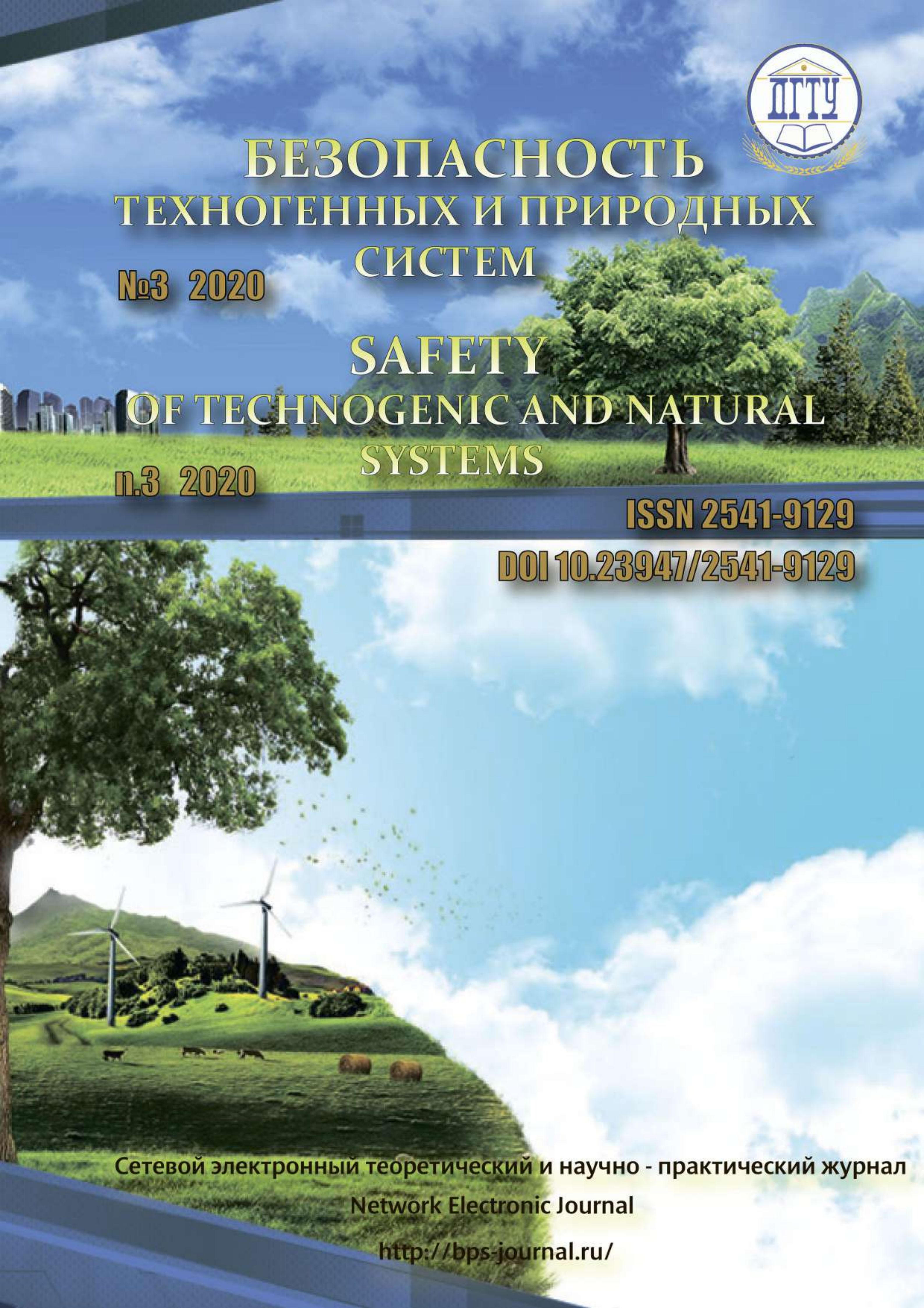

БЕЗОПАСНОСТЬ ТЕХНОГЕННЫХ И ПРИРОДНЫХ СИСТЕМ

№3 2020

SAFETY OF TECHNOGENIC AND NATURAL SYSTEMS

n.3 2020

ISSN 2541-9129

DOI 10.23947/2541-9129

Сетевой электронный теоретический и научно - практический журнал

Network Electronic Journal

http://bps-journal.ru/

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UDC 331.45
https://doi.org/10.23947/2541-9129-2020-3-2-6

Analysis of electrical injuries among workers

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Introduction. In the conditions of modern production, there is an increase in electrical injuries among workers. The article deals with the problem of injuries and characteristics of occurrence of electrical injuries in the workplace.

Problem Statement. The purpose of this study is to analyze statistical data and materials for investigating industrial injuries. The aim of the study is to determine the characteristic causes of electrical injuries in the workplace among workers and the main affecting factors.

Theoretical Part. The basic information used is the statistical data on occupational injuries provided by the Federal State Statistics Service.

Conclusion. The results of the analysis indicate that the main causes of electric injuries are organizational and psychophysiological factors. In order to improve safety and prevent injuries among workers, a comprehensive approach to risk assessment is needed, which will allow for the most complete consideration of all factors and conditions that contribute to the occurrence of electrical injuries in the workplace.

Keywords: electrical safety, electrical injury, injury causes, safe working conditions.

For citation*:* Pushenko S. L., Staseva E. V., Demchenko S. G., Nasonova S. Y., Tengaeva A. N. Analysis of electrical injuries among workers: Safety of Technogenic and Natural Systems. 2020;3: 2‒6. https://doi.org/10.23947/2541-9129-2020-3-2-6

Introduction. Currently, the level of injuries at work remains quite high. It is worth noting that we live in an era of industrial production development and a constant increase in electricity consumption. In modern production, a significant place is occupied by power plants and electric networks. All this creates prerequisites for increasing the risk of electrical injuries among workers. Thus, the study of the causes and factors of occurrence of electrical injuries is very important.

Problem statement. Analysis of statistical data on the state of injuries by industry in 2019 shows that the highest level of injuries is observed in the processing industry — 22.3%, mining — 19.3%, construction — 18.2%, agriculture accounts for 16.8% of cases, transport and communications — 11.8%, electricity — 7.8%, and other industries — 3.8% [1-3]. The distribution of injuries by type is shown in table 1.

The main types of injuries: falling from a height, moving objects, machines and mechanisms, road accidents. They account for up to 70% of all injuries. Cases of electrical injuries account for about 7.4% of injuries, but almost 40% of such injuries are fatal [2, 4-5]. All this, in the opinion of the authors, requires a more detailed study and analysis of the state of electrical injuries both at work and in everyday life.

Table 1

Distribution of injuries by type

Types of injury-risk factors in the production:	%
workers fall from a height	28,2
moving objects, machines, mechanisms	14,1
road accidents	14,4
collapses, objects fall on a person	13,1
electrical injuries	7,4
temperature effects	6,2
processed parts	5,1
toxic exposure, chemical burns	3,4
drowning	2,1
other factors	6,0

Theoretical part. Official Rosstat data for 2019 on electrical injuries are shown in figure 1.

— eye injuries are about 7%. Most often found among adults at the workplace;

— electric burns at home among adults — about 7%, among children — 5%. They account for 4,7% of industrial injuries;

— intracranial electrical injury among children reaches 13%, and among adults —11% [4].

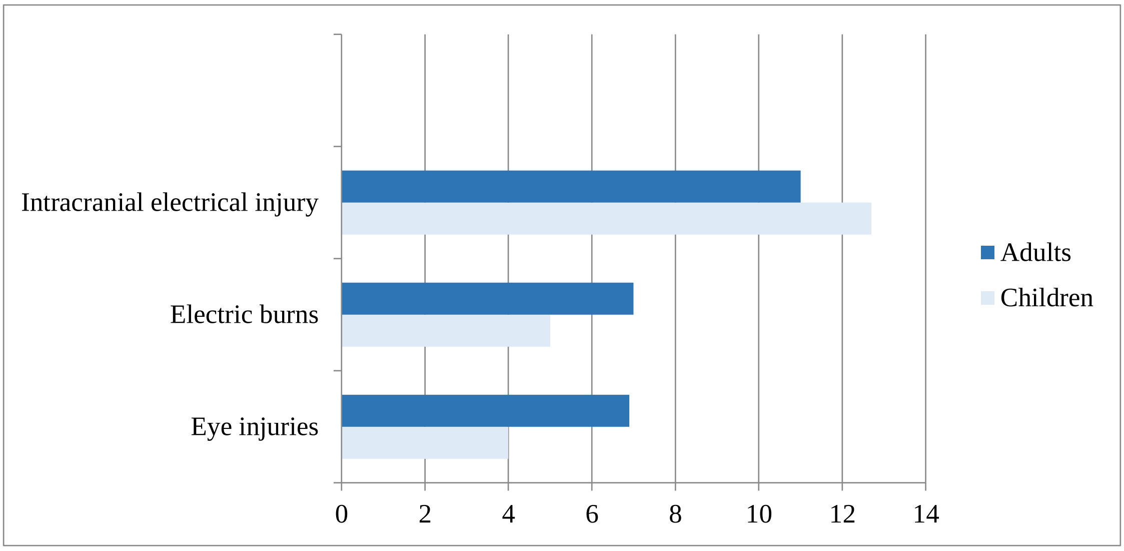

Fig. 1. Distribution of electrical injuries by types of injury

The danger of electric shock in production comes from sources of welding current, electric drives (including starting and control equipment), electrical equipment of lifting and transport devices, automated transport, induction and searchlight installations, electroplating hand-held tools, etc.

Effects of electric current on the human body can lead to various local electrical injuries (electric burn, skin metallization, electric mark and so-called general electric shock [5].

Electrical injury is the impact of electric current on a person with the development of deep functional disorders of organs and systems.

Electric burn is the most common electrical injury. Burns can be caused by an electric arc (arc burn) or contact with a live part (current burn) [2].

Skin metallization occurs in the case of mechanical or chemical current exposure, when inert or molten metal particles penetrate deep into the skin and the affected area becomes a solid surface.

An electric mark is a consequence of a thermal effect when a relatively large current flows through a small surface with a relatively large resistance at a temperature of 50-115°C with a good contact, resulting in coagulated, charred or swollen skin from close contact with live parts [6].

An electric shock leads to irritation of living tissues and is followed by involuntary convulsive muscle contractions when an electric current passes through the human body.

Electrophthalmia leads to inflammation of the outer membranes of the eyes, which occurs as a result of exposure to a powerful stream of ultraviolet rays of an electric arc.

Electric current affects the nervous system. This effect is very pronounced, since when an electric current passes through the body, a huge number of sensitive nerves are affected, the effect of electric current on skeletal muscles is very significant, as it causes spasm, and especially on the heart, causing its fibrillation. Most often, in such cases, death occurs, since the pumping function of the heart stops. Respiratory arrest or burn may also be a cause of death [4].

Influence of current on the human body depends on factors such as the body's resistance, amperage, duration of exposure, frequency and type of current, path of current flow in the body, the body condition and environmental conditions.

All this indicates a specific effect of electric current on a person, which most often leads to serious health disorders and death.

The main causes of electric shock among workers are:

— impact of electric current passing through the welding circuit;

— contact with open live parts and wires (accidental, not due to production necessity or due to incorrect power supply during repair and inspection);

— touching live parts that have a faulty circuit;

— touching parts with voltage through objects with low insulation resistance, metal parts of equipment that are overstressed (due to the absence or damage of protective devices) , etc.

Discussion and conclusion. The analysis of cases of electrical accidents at work have shown that 40-45% of the cases involve violations of the rules of operation of electrical installations, 25-30% of traumas — non-compliance with the safety requirements in the workplace and 30-35% of electrical shocks are caused by irregularities in the design of facilities, poor maintenance, presence of voltage on live parts of electrical installations. All causes are usually divided into technical, organizational, constructive and psychophysiological [7-9].

Thus, the issues of ensuring electrical safety in the workplace are still relevant today. The number of accidents resulting from electrical injuries is quite high, and a significant part of them are fatal. The main cause of electrical injuries is non-compliance with safety requirements. Therefore, in order to reduce the overall injury rates, it is necessary to study in more detail the cases of electrical injuries as a factor affecting the death rate at work [10].

To reduce cases of electrical injuries among workers, it is necessary to:

— improve the level of professional training of employees;

— provide high-quality training of employees in safe techniques and methods of work;

— timely monitor the condition and operability of power supply systems and power plants;

— conduct registration and analysis of psychophysiological causes of injuries as the most likely to occur in electrical injuries.

To ensure the electrical safety of workers, it is necessary to implement a comprehensive approach to risk assessment, which will allow for the most complete consideration of all factors and conditions that contribute to the occurrence of electric injuries [8]. Studying and solving problems related to ensuring healthy and safe working conditions is one of the most important tasks for the development of the economy and production in Russia. Comfortable and safe working conditions are one of the main factors affecting labor productivity, safety and health of employees.

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Submitted 01.06.2020
Scheduled in the issue 31.07.2020

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UDC 62-05 https://doi.org/10.23947/2541-9129-2020-3-7-15

Occupational morbidity in Russia: problems and solutions

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Introduction. The article presents the results of the analysis of the problems associated with occupational diseases in the country caused by adverse production factors. The facts of discrepancy between the official occupational diseases statistics and the assessment of the potentially possible number of them are established. The main reason for not registration of occupational diseases is the disinterest of the employer, employee and the commission, which conducts medical examinations, and also imperfection of legislative and standard base.

Problem Statement. The purpose of this study is to develop measures to reduce the level of morbidity caused by professional activity.

Theoretical Part. The problems associated with occupational diseases, factors that can and should solve the problem of ensuring the safety of production are considered, and measures are proposed to solve these problems.

Conclusion. The importance of the official registration of occupational diseases, their investigation and prevention is shown. Ways to solve problems both at the state level and at the enterprise level are proposed. The probabilistic assessment of harmful production factors affecting the risk of occupational diseases are determined. Key dependencies in the formation of occupational diseases at each specific enterprise are identified and the improvement of the enterprise's labor protection management system is proposed taking into account the risk of occupational diseases.

Keywords: occupational diseases, registration of occupational diseases, prevention of occupational diseases, production dependance of violations, assessment of the risk of occupational diseases obtaining and developing.

For citation*:* Vadulina N. V., Gallyamov M. A., Devyatova S. M. Occupational morbidity in Russia: problems and solutions: Safety of Technogenic and Natural Systems. 2020;3: 7‒15. https://doi.org/10.23947/2541-9129-2020-3-7-15

Introduction. As you know, unsatisfactory working conditions and unfavorable factors of the production environment are the main causes of occupational diseases. After reviewing the official statistics, which show 12-13 thousand cases of occupational diseases registered annually, we can conclude that this is several times lower than the indicators of countries with a fairly high level of safety culture. There is also a big difference in comparison with the statistics of the United States, where more than 500 thousand occupational diseases are registered annually [1]. Such widely differing figures raise reasonable doubts that official statistics reflect the true state of affairs.

Problem statement. Calculations carried out by the Research Institute of Occupational Medicine of the Russian Academy of Medical Sciences show an approximate proportion of the number of patients with occupational diseases from the number of employees undergoing mandatory medical examinations due to harmful working conditions, which is approximately 7.7 %. This is more than 60 thousand people and clearly exceeds the officially registered annual statistics, ranging from 9,000 to 12,000 cases per year [2]. In addition, a significant number of occupational diseases occur among employees who do not pass mandatory medical examinations, which also increases the estimated number of patients with occupational diseases.

Such a significant discrepancy between the officially registered occupational morbidity in the country and the potential (assumed) one is the evidence of a number of problems in this area.

We will try to identify them and suggest possible solutions, in the opinion of the authors.

Theoretical part. According to the regulatory requirements, three factors can and should solve the problem of ensuring production safety. This is the interest of the employer and employee. The state, regulating their interests, should guarantee the preservation of labor resources, quality and life expectancy of the population [3].

Of course, most of the problems associated with occupational diseases could be solved by improving the occupational health management system at the enterprise and sufficient funding for prevention measures.

Unfortunately, this is still a possibility, since the main goal of the employer is to get the maximum profit. Business considers investments in labor protection as necessary from the point of view of the law, but burdensome for itself. Registration of occupational diseases increases the level of social insurance for the employer (with a maximum surcharge of up to 40%), and simultaneously with the growth of direct costs, indirect losses appear [4].

The employee is also not interested in official confirmation of their professional illness, as this is often due to the need to change jobs [5].

The experience of conducting medical examinations of employees confirms this forced position of employees. Research shows that 85% of employees are not interested in detecting their occupational disease and prefer to continue working, to have legally established benefits (compensation) for working in harmful working conditions instead of establishing an occupational disease [6]. An employee engaged in work with harmful or dangerous working conditions has a minimum wage increase of 4 % of the salary of an employee with normal working conditions (article 147 of the Labour Code), a shortening of the duration of working time not exceeding 36 hours per week (article 92 of the LC RF), guaranteed annual additional paid vacation with minimum duration of 7 calendar days (article 117 of the Labour Code).

Official registration of an occupational disease requires a transfer, usually to a less paid job, or a search for an excuse to get rid of a problem employee.

The failure to report cases of occupational disease by commissions conducting medical examinations of employees is due to a number of reasons:

— lack of motivation to detect occupational diseases among doctors conducting examinations. For comparison, in European countries, a doctor receives remuneration from an employer for identifying a patient with signs of an occupational disease. In our country, a medical organization with a high degree of detection of occupational diseases risks losing an employer as a client.

— insufficient training of doctors participating in examinations in the specific features of the clinical course of occupational diseases [7].

Under the current conditions, only the government can and should change the situation in the field of prevention, detection and registration of occupational diseases by creating an effective model in cooperation with employers and trade unions. This is a serious resource for achieving success in the government's program to ensure high life expectancy in the country. Of course, the main direction should be the development of prevention of industrial injuries and occupational diseases.

Let us focus on a qualitatively new approach to the organization of prevention, which combines three areas: safety, occupational health and well-being of employees at all levels of production. The entire modern world participates in the Vision Zero movement.

The essence of the Vision Zero concept is the development of prevention of industrial injuries and occupational diseases, which allows you to eliminate the causes of accidents and prevent accidents at work. In April 2018, the Vision Zero campaign was launched in Russia. In our country, the function of social and financial protection of the working population is performed by the Social Insurance Fund (SIF RF). For citizens who work under labor contracts, employers pay contributions to the Social Insurance Fund. These funds provide guaranteed payments for medical, social and professional rehabilitation after an accident at work. They can also be used to finance measures for accident prevention, to increase the economic interest of employers in improving working conditions and safety. That is why the International Social Security Association (ISSA) awarded the SIF of the Russian Federation the certificate of the official partner of the program to promote the Vision Zero concept.

Unfortunately, the SIF works with the consequences of tragedies when nothing can be corrected. However, efforts should be directed towards accident prevention.

Such measure as the financing of preventive measures on reducing industrial traumatism and occupational diseases, which is due to the amounts of insurance contributions is aimed at increasing the economic interest of the employer in ensuring safe labor conditions

All policyholders, regardless of their organizations' form of ownership, type of activity and the number of employees, have the right to preventive measures financial support for labor protection at the expense of insurance premiums.

For this purpose, you can spend no more than 20% of the amount of insurance premiums for the previous calendar year, minus the cost of paying injury benefits. For the purpose of economic incentives for employers to improve working conditions, it is possible to raise the bar, for example, to 30% of the amount of insurance payments, especially since the costs are spent on specific measures to prevent injuries and occupational diseases.

Since 2019, twelve measures to provide financial support for preventive measures, including reimbursement of costs for training in labor protection, the purchase of personal protective equipment (PPE), breathalyzers, tachographs, periodic medical examinations, provision of therapeutic and preventive nutrition, and a number of others, have been added with one more — sanatorium-resort therapy of employees of preretirement age [8].

However, it should be borne in mind that the cost of purchasing PPE is compensated only if the products are made on the territory of Russia and from domestic materials. The purchase of the imported PPE will not be financed.

It is prevention that is recognized as the most promising — it is better to prevent accidents, injuries and diseases than to deal with their consequences.

The SIF uses legal instruments to influence the economic interest of employers in reducing the level of industrial injuries and occupational diseases through discounts and surcharges to the insurance rate. The amount of discounts (surcharges) depends on the level of occupational injuries and occupational diseases, as well as labor protection conditions.

The economic interest of employers is that employers who have a minimum level of occupational injuries have the right to apply for a discount to the insurance rate. And vice versa, if the company's indicators for the level of occupational injuries exceed the indicators established by the current legislation, the employer must be set a surcharge to the insurance rate.

The amount of the discount or surcharge is set taking into account information about the special assessment of working conditions (SAWC), and the calculation takes into account the results of mandatory medical examinations of employees. Organizations that have conducted SAWC and provide medical examinations of employees are entitled to receive a discount to the insurance rate. The amount of the discount (surcharge) can reach 40% of the established insurance rate.

If the employer is not motivated to create favorable working conditions at his enterprise, the result is the payment of insurance premiums in an increased amount, which is increased by the amount of the established allowance. The highest surcharge (40%) is "earned" by policyholders who have no interest in taking measures to reduce the level of occupational injuries.

The SIF sets the premium to the insurance rate independently [9].

To ensure objectivity in the detection and registration of occupational diseases, it would be useful to return to the existing practice that obliges managers of industries with harmful and dangerous factors (a large set of factors and the number of employees) to conclude contracts with certain medical institutions specializing in the identification and treatment of workers with occupational diseases and regular medical examinations. To increase the responsibility of medical institutions for the completeness of detection of primary signs and occupational diseases themselves, they use the regulatory and legislative framework for assessing the quality of medical care, which includes such concepts as the quality of diagnosis, creating conditions for increasing the risk of a new pathological process.

Federal law No. 326-FZ of 29.11.2010 (ed. from 01.04.2020 No. 98-FZ) "On compulsory health insurance in the Russian Federation" states: "Examination of medical care quality is the detection of violations in the provision of medical care, including assessment of the timeliness of delivery and the correct choice of methods of prevention, diagnosis, treatment and rehabilitation, the achievement of the planned results" [10].

The Order of the Ministry of Public Health and Social Development of Russia dated 12.04.2011 No. 302n (ed. by 18.05.2020) "On the approval of lists of harmful and (or) dangerous production factors and works, under which compulsory preliminary and periodic medical examinations (surveys), and the Order of the obligatory preliminary and periodic medical examinations (surveys) of workers in physically demanding jobs and working with harmful and (or) hazardous working conditions," says that medical board must be led by occupational physicians.

The mentioned Order, on the one hand, significantly increases the number of employees subject to preliminary and periodic examinations, since the list of works that require these examinations has almost doubled. On the other hand, according to the Order, examinations should be carried out only for employees engaged in work with harmful heavy working conditions. However, there is official data that even at the acceptable level of HPF (class 2), occupational diseases are registered: in 2010, they were 2.6%, and in 2011 — 3.78% [11].

It is necessary to make changes to the regulations on occupational diseases for the mandatory examination of all employees who come into contact with harmful production factors, regardless of the class of working conditions.

You can also criticize the List of occupational diseases approved by Order No. 417n of the Ministry of Public Health and Social Development of the Russian Federation dated April 27, 2012 "On approval of the List of occupational diseases". Only the diseases specified in it can be determined [12].

International Labour Organization (ILO) Convention No. 121 of 1964 established the List of occupational diseases for the first time [12]. In 1980, the 66th international labour conference updated this List. However, there is still no generally accepted and unified classification of occupational diseases. Each ILO member country sets its own list of occupational diseases and defines measures for their prevention and social protection of victims.

In the Russian Federation, there is a List of occupational diseases approved by Order No. 417p of 27.04.2012 of the Ministry of Public Health and Social Development of Russia. This list is the main document that is used when establishing the diagnosis of an occupational disease, its connection with the work performed or profession, when solving issues of examination of working capacity, medical, social and labor rehabilitation, as well as when considering issues related to compensation for damage caused to an employee and damage to health. The specified list of occupational diseases includes diseases that are caused solely or primarily by exposure to harmful, dangerous substances and production factors [12].

The list of occupational diseases approved by the ILO for the first time in 1964 was updated by the ILO in 1980 without the adoption of new legislative documents. The next version of the List appeared only 22 years later.

The work on the revision of the list of occupational diseases was carried out by a group of ILO experts in 2005-2009 and in 2010. The ILO governing body approved an updated the list of occupational diseases, which includes 40 occupational intoxications (including 9 new ones: from nickel, platinum, ammonium, isocyanates, pesticides, sulfur oxides, organic solvents, latex, chlorine), 6 occupational diseases from the action of physical factors (including optical radiation, including laser radiation), 8 occupational diseases caused by biological factors that were not detailed in the old version of the list (brucellosis, viral hepatitis, human immunodeficiency virus, tuberculosis, etc.).

The section "Professional cancer" is supplemented with 6 new factors: arsenic, beryllium, cadmium and their compounds, erionite, ethylene oxide, Hepatitis b and C viruses and now contains twenty diseases [13].

The above mentioned requires changes to the List of occupational diseases of the Russian Federation in accordance with the legislative List of diseases proposed by the ILO.

Also, the need to simplify the cumbersome system of establishing the final diagnosis of occupational diseases in Russia should be attributed to the measures of state regulation for the preservation of personnel. It is two-stage: the suspicion of the doctor of the polyclinic, and the final diagnosis is made by a specialized center of occupational pathology. Why can an ordinary doctor of a polyclinic finally make a diagnosis (for example, flu, pneumonia, polyneuropathy, glaucoma, sensorineural hearing loss, etc.), but does not have the right to make a diagnosis of an occupational disease? There is no answer to this question yet.

With the aim of changing management approaches in the sphere of labor protection, the Ministry of Labor has prepared and submitted to the Government of the Russian Federation a Draft Federal law providing for the addition to the Labor code with the conceptually new standards.

The main goals of the draft law are to increase the effectiveness of prevention of occupational injuries and occupational diseases, increase the dynamics of reducing group, severe and fatal injuries, and increase the level of safe work culture.

Main changes and additions proposed by the draft law:

1) introduction of accounting for microtraumas received by employees and analysis of their causes, as a basic principle of prevention of occupational diseases, based on the constant identification of hazards in the workplace, analysis and elimination of the causes of these hazards to improve working conditions;

2) personal participation of employees in ensuring safe working conditions at their workplaces, manifested in:

— informing employees about the existing hazards when performing work;

— refusal of the employee to perform official duties if safe working conditions are not provided. Thus, it is possible to ensure the introduction of a ban on working in dangerous working conditions;

3) changing the approach to providing employees with PPE by switching from the list principle of security to security depending on the specific working conditions at the workplace, taking into account the specifics of the working conditions of employees;

4) introduction of the institute of employer's self-assessment of the compliance with labour legislation, which will be held on a pre-formed by Rostrud list of issues.

The adoption of this law will:

— give new impetus to improving working conditions in the workplace;

— maintain positive dynamics of reducing the number of occupational diseases, deaths and injuries due to accidents and occupational diseases;

— provide a reduction in administrative burden and greater flexibility for the employer in building a modern occupational health management system based on systematic analysis, assessment and reduction of the existing occupational risks;

— raise awareness of employees about working conditions in the workplace, about existing occupational risks, guarantees provided to them, compensations and PPE, as well as to ensure the involvement of employees in ensuring appropriate working conditions [14, 15].

According to the authors, the proposed improvements to the legislative, regulatory, and local labor safety management framework will have a significant impact on solving the problems of occupational diseases in the country.

However, even the full implementation of the planned changes will not eliminate the relevance of occupational disease prevention. Therefore, to develop effective measures for the prevention of occupational diseases, we suggest that employers use the algorithm of combined risk assessment for getting and developing occupational diseases with ranking criteria for a special assessment of working conditions. The main resource of the enterprise is personnel, so forecasting risks and detecting pathological changes in the body at an early stage should become a priority task for preserving the health and working capacity of the staff.

Professional risk assessment allows you to monitor its occurrence and rank its specific indicators. On this basis, an algorithm for assessing occupational risk has been developed, which makes it possible to scientifically justify professional groups for assessing the risk of staff morbidity and reduce the impact of harmful factors.

The algorithm for combined risk assessment of occupational diseases with ranking criteria for special assessment of working conditions was developed on the example of oil-production enterprises, since they are complex natural and man-made systems, where processes can lead to accidents and the emergence of occupational diseases.

Currently, workers employed primarily in the main technological operations of oil-production enterprises are exposed to harmful and dangerous production factors, namely vibration (45 %), increased noise (40 %), difficult working conditions (21 %), chemical factors (11%), unfavorable microclimate (9%), dust (9%), which lead to the development of occupational diseases. The analysis carried out at oil production enterprises shows 170 cases of occupational diseases in 122 employees. In addition to the main type of occupational diseases, concomitant diseases have also been identified. Employees are often diagnosed with 2-3 occupational diseases, which is explained by a variety of effects of harmful production factors on the body of an employee of the oil industry.

Based on the results of the assessment of occupational risks, it can be concluded that the degree of industrial conditionality of violations in the body systems of personnel depends on the length of service, profession, but mainly on the degree of harmfulness of working conditions. The overall assessment of the situation shows a very high degree of industrial conditionality of diseases of the musculoskeletal system, diseases of the hearing organs, which indicates their strong relationship with working conditions. The average degree of industrial conditioning is assigned to cardiovascular and respiratory diseases.

According to the results of the analysis of the impact of production conditions on the human body and the results of the quantitative assessment of working conditions there was proposed an integrated scoring of specific severity of the industrial processes negative factors based on probabilistic assessment of hazardous occupational factors influencing the risk of occupational diseases, risk assessment of the production conditionality of health problems and the expert and statistical evaluation of cases of occupational diseases.

The probabilistic assessment of harmful production factors affecting the risk of occupational diseases is determined by the occupational diseases index ($И_{пз}$) — a single-digit indicator that takes into account both the probability and the severity of occupational diseases by their categories:

$$И_{пз}=1/(К_р \times К_т),$$

where $К_р$ — risk category, $К_т$ — severity category.

The use of the inverse value of the product of these categories allows us to evaluate occupational diseases qualitatively and quantitatively with an integral indicator that lies within the range of $0 < И_{пз} < 1$.

The risk assessment of occupational health conditions was assessed by the index of professionally determined diseases (PDD), a single-digit indicator that is the inverse of the product of the risk, severity, and work-related categories:

$$И_{поз}=\sum I_i\,[1/(К_р \times К_т \times К_с)],$$

where $К_с$ — is the work-related category, i = 1, 2, 3 ... = n — is the number of diseases

$К_р$ = 1, 2, 3 etc. corresponds to the values of PDD >10 %, 1–10 %, <1 % etc. $К_т$ = 1, 2, 3 correspond to the medical prognosis of the disease and the type of disability it causes. $К_с$ = 1, 2, 3, 4, 5 accepted on the scale of assessment of the connection of health disorders with work.

As a result, depending on the prevalence rate, severity, and relationship of the disease to work (or the environment), the index ranges from 0 to 1, i.e. $0 < И_{поз} < 1$. For a set of diseases $И_{поз} > 1$ is possible.

Occupational risk assessment allows you to monitor the risk of occupational disease and rank its specific indicators:

Ultra-high risk ($И_{пз} > 1.0$)
Very high risk ($И_{пз} = 0.5\text{-}1.0$)
High risk ($И_{пз} = 0.25\text{-}0.49$)
Medium risk ($И_{пз} = 0.12–0.24$)
Low risk ($И_{пз} = 0.05–0.11$)

Ranking of occupational risk values makes it possible to scientifically justify professional groups for assessing the risk of staff morbidity and reduce the impact of harmful factors (Fig. 1).

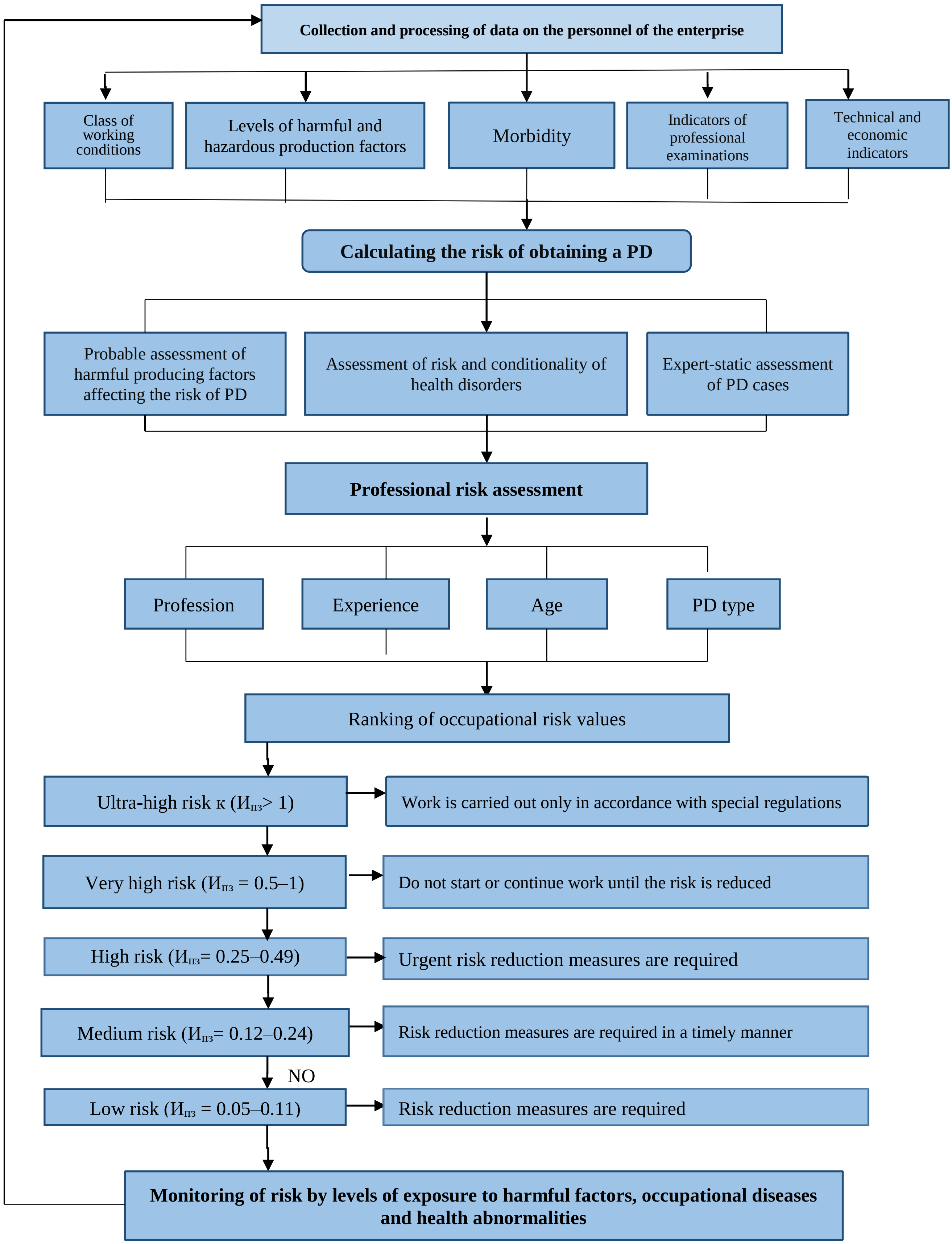
Collection and processing of data on the personnel of the enterprise
Class of working conditions
Levels of harmful and hazardous production factors
Morbidity
Indicators of professional examinations
Technical and economic indicators
Calculating the risk of obtaining a PD
Probable assessment of harmful producing factors affecting the risk of PD
Assessment of risk and conditionality of health disorders
Expert-static assessment of PD cases
Professional risk assessment
Profession
Experience
Age
PD type
Ranking of occupational risk values
Ultra-high risk к ($И_{пз}$> 1)
Work is carried out only in accordance with special regulations
Very high risk ($И_{пз}$ = 0.5–1)
Do not start or continue work until the risk is reduced
High risk ($И_{пз}$= 0.25–0.49)
Urgent risk reduction measures are required
Medium risk ($И_{пз}$= 0.12–0.24)
Risk reduction measures are required in a timely manner
NO
Low risk ($И_{пз}$ = 0.05–0.11)
Risk reduction measures are required
Monitoring of risk by levels of exposure to harmful factors, occupational diseases and health abnormalities

Fig. 1. Algorithm for assessing the risk of getting and developing of occupational diseases

Conclusions. Thus, this article identifies ways to solve problems related to occupational diseases, both at the state level and at the enterprise level. The importance of official registration of occupational diseases, their investigation and prevention is shown. A probabilistic assessment of harmful production factors affecting the risk of occupational diseases and the assessment of the risk of industrial conditionality of health disorders was carried out. The analysis revealed that the acceptable risk (1×10-3) for professional groups, while maintaining the technology of work and working conditions, is provided by limiting the length of service to 3-4 years. The key dependencies in the formation of PD at each specific enterprise are revealed.

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Submitted 19.06.2020
Scheduled in the issue 16.07.2020

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UDC 331.436 https://doi.org/10.23947/2541-9129-2020-3-16-20

Peculiarities of labor conditions and safety of the electric welder of manual welding

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Introduction. The article considers peculiarities of working conditions of electric welders of manual welding. The analysis of the results of the special assessment of working conditions and protocols of measurement of production factors at the workplace was carried out.
Problem Statement. The purpose of this study is to analyze the results of a special assessment of working conditions and develop measures to improve working conditions.
Theoretical Part. The influence of various factors on the employees of this profession has been studied and the main occupational diseases to which electric welders are exposed have been considered. The article proposes a number of measures to improve the working conditions and safety of workers.
Conclusion. The results of the analysis indicate a high impact of harmful factors on the employee and the need to develop measures to improve working conditions.

***Keywords*:** labor protection, harmful production factors, working conditions, electric welder.

For citation: Staseva E. V., Demchenko S. G., Oniskovets Yu. M. Peculiarities of labor conditions and safety of the electric welder of manual welding: Safety of Technogenic and Natural Systems. 2020;3: 16–20. https://doi.org/10.23947/2541-9129-2020-3-16-20

Introduction. According to statistics of the all-Russian Research Institute of Labor (VNII Truda), from 2001 to 2018, the number of injured workers decreased by more than 6 times (Fig. 1) [1].

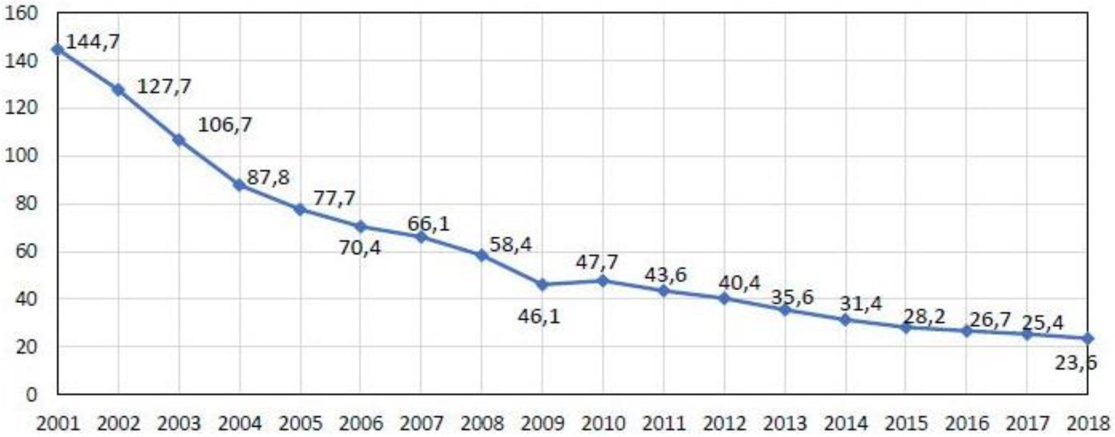

Fig. 1. Dynamics of the number of injured workers (thousand people). Accidents with loss of labor capacity for one day or more and resulting in death from 2001 to 2018

Experts of the Institute of Labor noted that the level of occupational injuries significantly (more than 3 times) decreased from 2001 to 2009. A slight increase was recorded in 2009-2010. Then the situation began to improve again, and by 2018 the number of victims decreased by 2 times. Over the entire period under review, there were 3.6 times fewer deaths.

Fig. 2 provides the data on the demand for electric welders.

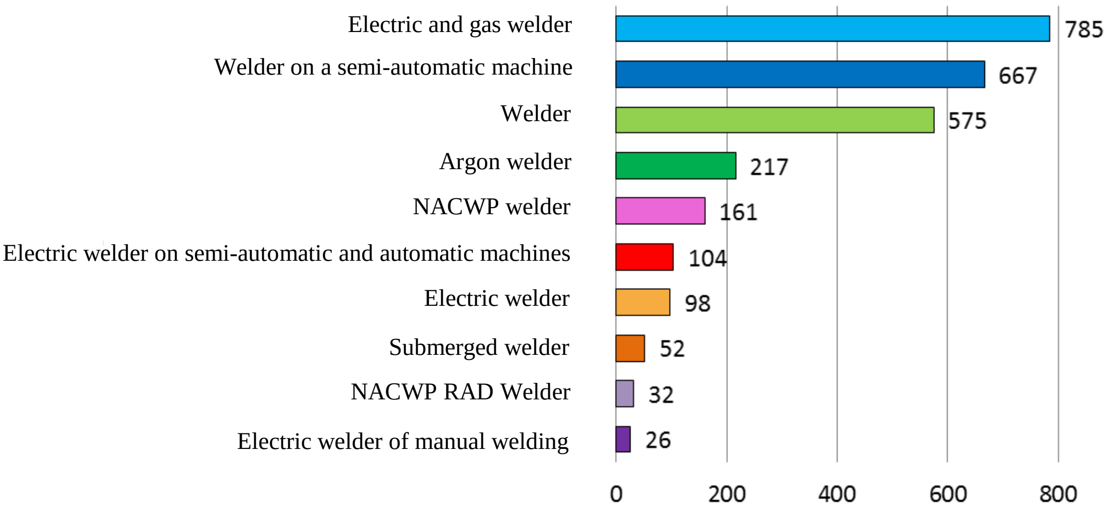

Fig. 2. Number of open vacancies for welders at Russian enterprises in 2019

The study of safety issues for electric welders is becoming increasingly important. Competent organization increases productivity in many times, reduces the possibility of injuries, and occupational diseases associated with the work of welders [2].

Problem statement. The relevance of the topic is confirmed by statistics on injuries and occupational diseases among welders. Welders account for 11.5 % of construction injuries [3]. This is due, among other things, to the failure of employees to comply with safety requirements in the production of electric welding works. Welders are affected by harmful and dangerous production factors of physical and chemical nature: emissions of harmful chemicals, radiation, sparks, dust, etc. [4]. Thus, the welding process is potentially dangerous for the worker. This makes it necessary to take measures to prevent adverse situations during welding operations.

Theoretical part. Welding and cutting with electrodes involves the operation of equipment and the use of substances that can cause injuries, accidents, fires, etc. in case of improper handling or violation of work rules. Some compounds used in welding pollute the environment and can affect the employee's body as toxic substances [2, 5].

The most typical types of injuries during electric welding operations [6]:

— electric shock,

— damage to the eyes and open skin surface by electric arc radiation,

— burn from drops of metal and slag,

— poisoning of the body with harmful gases, dust and fumes.

There are also many other hazards that can lead to accidents at work.

The air of the working area of electric welding contains nitrogen dioxide, carbon oxide and manganese. The most harmful gases released during welding include nitrogen, carbon and ozone oxides. If the work is carried out indoors or for a long time, these elements can cause irritation of the respiratory tract, mucous membranes, eyes, dry mouth, etc. [7]. The severity of labor is a characteristic of the labor process that reflects the load on the musculoskeletal system and functional systems of the body (cardiovascular, respiratory, etc.). The greatest discomfort during welding is caused to electric welders by a forced uncomfortable position when connecting welding joints.

Also, at the workplace of a manual welding specialist, there are fibrogenic aerosols, which include iron particles. Strongly fibrogenic aerosols are dust of industrial origin that contribute to the development of dust diseases of the lungs (connective tissue grows in the lungs, disrupting the normal structure and function of the organ) [4].

The workplace measurement protocols also record the impact of noise on the employee. In the technological process, when working with welding equipment, noise sources are:

— welding process,

— welding equipment,

— preparatory operations (straightening, assembling, cutting, working with hand grinders), etc.

Noise has an irritating effect on a person, reduces performance. The perception of information is getting worse. Various unhealthy conditions may develop, including hearing loss and deafness.

Thus, welders with more than ten years of experience are predisposed to dust bronchitis, pneumoconiosis, eczema, manganese intoxication, etc. [8].

A special assessment showed that 95 % of electric welders work in harmful conditions. The most harmful factors are:

— chemical (working conditions class 3.1),

— non-ionizing ultraviolet radiation (working conditions class 3.1),

— severity of work (working conditions class 3.1).

Final class of working conditions is 3.2.

Based on the results of calculations of the influence of all production factors, an ultra-high risk was determined — 7.51 [9]. The calculations have shown that the employee's life expectancy is reduced by 739 days due to working conditions. The maximum risk of death for a manual welding specialist in production — 1.22×10– 4 [9-11].

To reduce the described risks, we should adopt a management strategy that involves the use of modern means of protection [12, 13].

Conclusion. In order to reduce the impact of harmful production factors and prevent the development of occupational diseases for manual welding specialists, the following is necessary:

— inspections, examinations and tests, technical inspections and diagnostics of the ventilation system;

— laboratory control of the content of harmful substances in the air of the working area;

— compliance with the schedule of medical examinations;

— reduction of the impact of elevated levels of chemicals in the work area air;

— certification testing of employees for knowledge of safety and labor protection rules;

— compliance with the rational mode of work and rest, increasing breaks (reducing the severity of the labor process);

— use of new modifications of respirators, protective masks and suits during welding operations.

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Submitted 01.06.2020
Scheduled in the issue 20.07.2020

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Contribution of the authors:

E. V. Staseva — scientific supervision, analysis of research results, revision of the text, correction of conclusions; S. G. Demchenko — scientific supervision, analysis of research results, revision of the text, correction of conclusions; Yu. M. Oniskovets — formulation of the main concept, goals and objectives of the research, calculations, preparation of the text, conclusions.

UDC 614.849 https://doi.org/10.23947/2541-9129-2020-3-21-32

Territorial fire statistics and assessment of their causes and consequences on the example of the Rostov region

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Introduction. A deep and comprehensive analysis of the parameters of the situation with fires in the territories of the Russian Federation and its relationship with socio-economic processes is more relevant than ever for Russia. The article presents, summarizes and analyzes statistical data on the situation with fires and their consequences on the territory of the Rostov region for 2018-2019.

Problem Statement. The paper considers the problem of official statistical accounting of fires, the procedure for accounting for people killed and injured in a fire in the context of a changing regulatory framework in this area. The analysis of the situation, official and verified information on fires and their consequences will create a reliable socio-economic characteristic of the Rostov region.

Theoretical Part. The paper deals with the peculiarities of accounting of fires and their consequences in Russia. The source materials are the official statistics of the MD of the MES of Russia for the Rostov region on the number of fires on the territory, months, the number of people injured and killed in fires and their distribution by gender, age and time of death, objects and causes of fires.

Conclusion. The analysis of fire statistics on the territory of the Rostov region for 2018-2019 is based on official data of the MD of the MES of Russia for the Rostov region, which indicates the reliability of the information provided. Statistical data were evaluated for key factors affecting fire safety: by the number of fires on the territory of the Rostov region, days of the week, months, the number of people injured and killed in the fires and their distribution by gender, age and time of death, objects and causes of fires. Research prospects are outlined.

Keywords: fire situation, statistics, consequences and causes of fires, fire objects.

For citation*:* Ustin V. G., Bulygin Yu. I., Tretyakov P. P., Maslenskiy V. V. Territorial fire statistics and assessment of their causes and consequences on the example of the Rostov region: Safety of Technogenic and Natural Systems. 2020;3: 21‒32. https://doi.org/10.23947/2541-9129-2020-3-21-32

Introduction. A deep and comprehensive analysis of the parameters of the situation with fires in the territories of the Russian Federation and its relationship with socio-economic processes is relevant for Russia. On the example of the Rostov region, the dynamics of fire distribution by causes and objects of occurrence and localities is considered. It also provides statistical information on the age, time of day, days of the week, months, and physiological state of people who died or were injured in a fire. This detailed analysis of statistical data processing will allow for a more correct approach in the future to develop a number of recommendations for improving fire risk management.

Problem statement. The authors comprehensively consider the problem of official statistical accounting for fires, the procedure for accounting for people killed and injured in a fire in the context of a changing regulatory framework in this area. The analysis of the situation, official and verified information on fires and their consequences will create a reliable socio-economic characteristic of the Rostov region.

Specifics of the procedure for registering data on fires and their consequences in the Russian Federation. In order to comply with the provisions of key legal documents [1-3] regulating the procedure for registering data on fires and their consequences in the Russian Federation, a unified state system for statistical accounting for fires and their consequences is functioning, the main activity of which is legally performed by the State Fire Safety Service of the EMERCOM of Russia. The official information on fires and subsequent negative events is generated by Rosstat [4].

The Department of Supervision and Preventive Work of the Ministry of Emergency Situations of Russia prevents the occurrence of fires in various regions of the Russian Federation and eliminate their consequences. Its tasks are:

— getting information from the respondents on fires that caused injury or death;

— analysis of the information received and its provision to the state structures that carry out fire supervision;

— receiving, processing and submitting the administrative information on fires that caused injury or death to the Federal state budgetary institution Fire Safety Research Institute EMERCOM of Russia [5].

The coordination of work on the registration of data on fires and their consequences is entrusted to the official statistical office, which performs monitoring, data analysis and statistics on the distribution of the number of fires, dead and injured people. The observation stage is based on statistical and administrative information collected by the respondents [6].

Registration of data on fires and their consequences at the state level is carried out on the basis of:

— reports on fires and their consequences provided by the Department of Supervision and Prevention of the EMERCOM of Russia;

— reports on fires and their consequences, provided by the Federal bodies of Executive power in the subordinate objects.

Since January 1, 2019, statistics have changed, the concept of "catching fire" was excluded. Now it is assumed to account for people who have received injuries that are the reasons for their hospitalization or need outpatient treatment.

The established procedure for registering data on fires and their consequences is mandatory for state authorities, local self-government bodies, organizations and citizens engaged in business activities without forming a legal entity [7].

Official statistical information on fires and their consequences is publicly available, except for information that is restricted by Federal laws.

Territorial fire statistics. In 2019, the situation with fires in the Rostov region, compared to the same period of the previous year (hereinafter referred to as the SPPY), had the following main indicators:

— 91 9175 fires were recorded (SPPY — 13964 (–34.3 %);

— 191 people were killed in the fires (SPPY — 210 (-9.04%), of which 3 were children (SPPY — 15 (-80.0 %);

— 224 people were injured in fires (SPPY — 277 (-19.1 %);

— direct material damage was caused in the amount of 294 million 336 thousand rubles. (SPPY — 248 million 15 thousand rubles (+18.7 %).

The Federal Fire-Fighting Service units saved 4,130 people and property worth 2 billion 722 million 652 thousand rubles during the fires.

Figure 1 shows the distribution of the number of fires in the Rostov region by months. As it can be seen from the graph, compared to the same period in 2018, there was an increase in the number of fires in February by 40.2 %, in March by 83.2 %, and in November by 48.3 %. In the remaining months of the year, a decrease in the number of fires was recorded [8, 9].

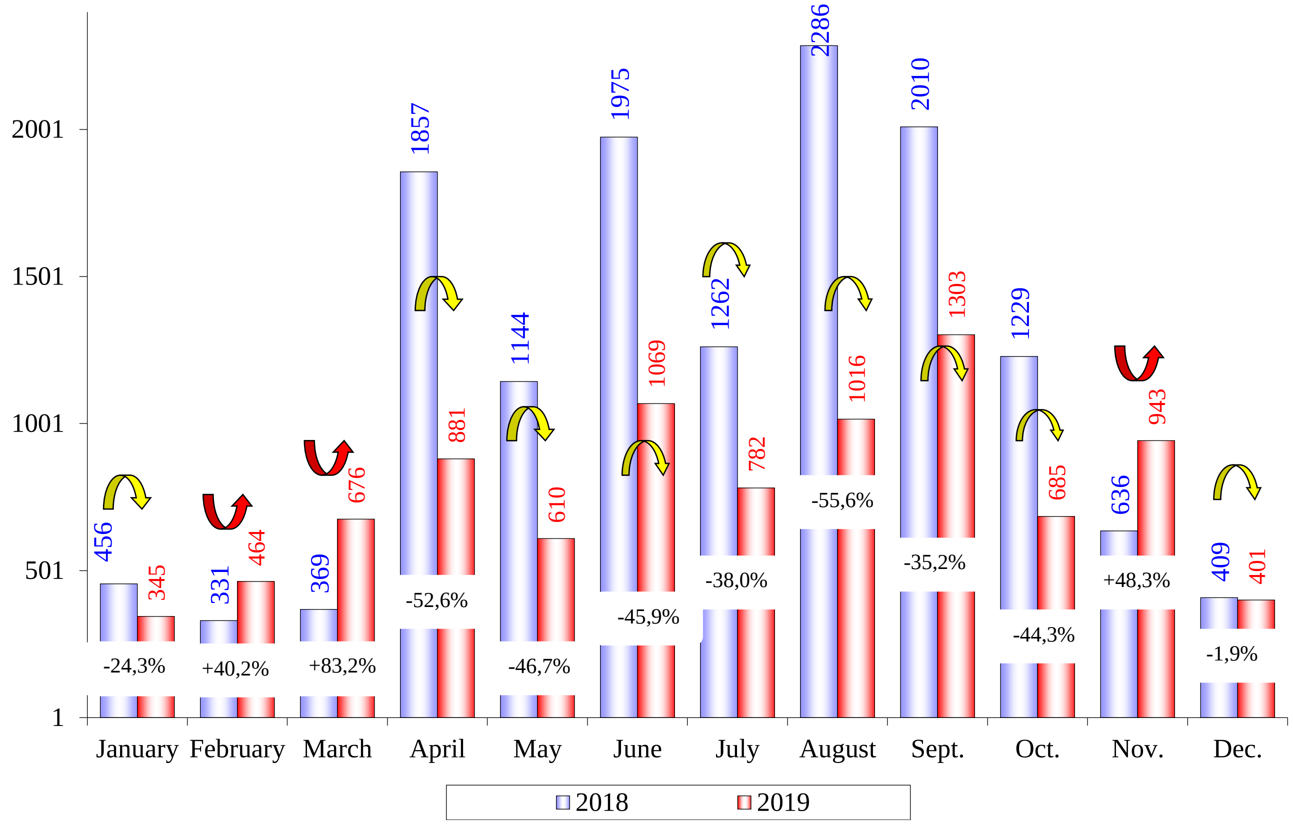

Fig. 1. Distribution of the number of fires in the Rostov region by month

The reduction in the number of people killed was registered in 25 municipalities: Bataysk (–50.0 %), Gukovo (–80.0 %), Zverevo (–100 %), Taganrog (–33.3 %), Shakhty (–30.0 %), Aksay (–22.2 %), Belokalitvinskiy (–42.9 %), Veselovskiy (–100 %), Dubovskiy (–33.3 %), Egorlykskiy (–25.0 %), Zavetinskiy (–100 %), Zernogradskiy (–83.3 %), Kagalnitskiy (–100 %), Kasharskiy (–50.0 %), Konstantinovskiy (–66.7 %), Krasnosulinskiy (–87.5 %), Kuybyshevskiy (–100 %), Millerovskiy (–50.0 %), Oblivskiy (–80.0 %), Rodionovo–Nesvetayskiy (–25.0 %), Semikarakorskiy (-50.0 %), Tarasovskiy (–100 %), Ust–Donetskiy (–80.0 %), Chertkovskiy (–100 %), Volgodonskiy (s) (–66.7 %) districts (Fig. 2).

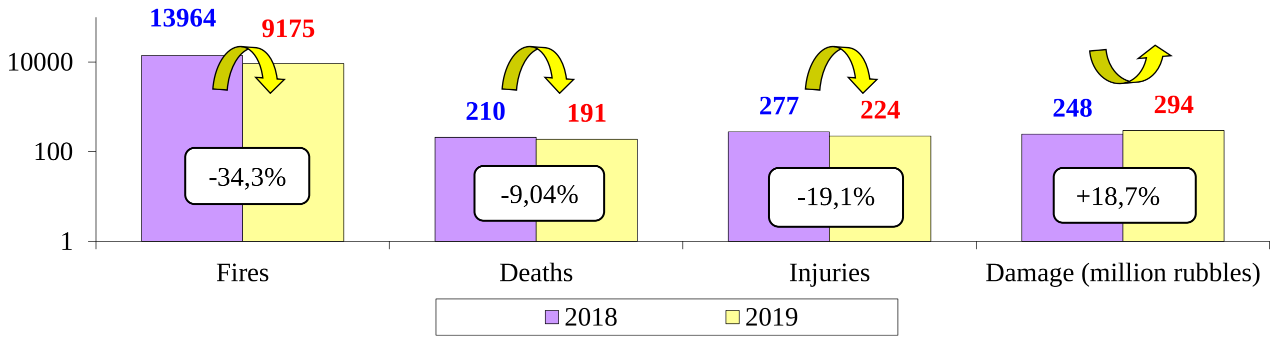

Fig. 2. Number of fires and people killed in the Rostov region

The decrease in the number of people injured in fires occurred on the territory of 23 municipalities: Rostov-on-Don (–15.4 %), Azov (–75.0 %), Bataysk (–100%), Volgodonsk (–75.0 %), Gukovo (–66.7 %), Donetsk (–100 %), Novocherkassk (–53.9%), Novoshakhtinsk (–18.2 %), Shakhty (–70.0 %), Bagaevskiy (–50.0 %), Dubovskiy (–60.0 %), Egorlykskiy (–66.7 %), Zimovnikovskiy (–25.0 %), Kamenskiy (s) (–25.0 %), Matveevo–Kurganskiy (–75.0 %), Milyutinskiy (–100 %), Oblivskiy (–100 %), Oktyabrskiy (s) (–33.3 %), Salskiy (–57.1 %), Semikarakorskiy (–60.0 %), Tarasovskiy (–67.7 %), Chertkovskiy (–50.0 %), Volgodonskiy (–50.0 %) districts.

An increase in the number of people injured in fires was recorded in Zverevo (+50.0 %), Kamensk-Shakhtinsk (+100 %), Azov (+42.9 %), Aksay (+50.0 %), Veselovskiy (+100 %), Sholokhovskiy (+100 %), Zavetinskiy (+100 %), Zernogradskiy (+50.0 %), Kagalnitskiy (+100 %), Konstantinovskiy (+100 %), Kuybyshevskiy (+100 %), Martynovskiy (+100 %), Morozovskiy (+100 %), Myasnikovskiy (+100 %), Neklinovskiy (+30.0 %), Remontnenskiy (+50.0 %), Tatsinskiy (+100 %), Tsimlyanskiy (+100 %), Sovetskiy (s) (+100 %) districts (Fig. 3).

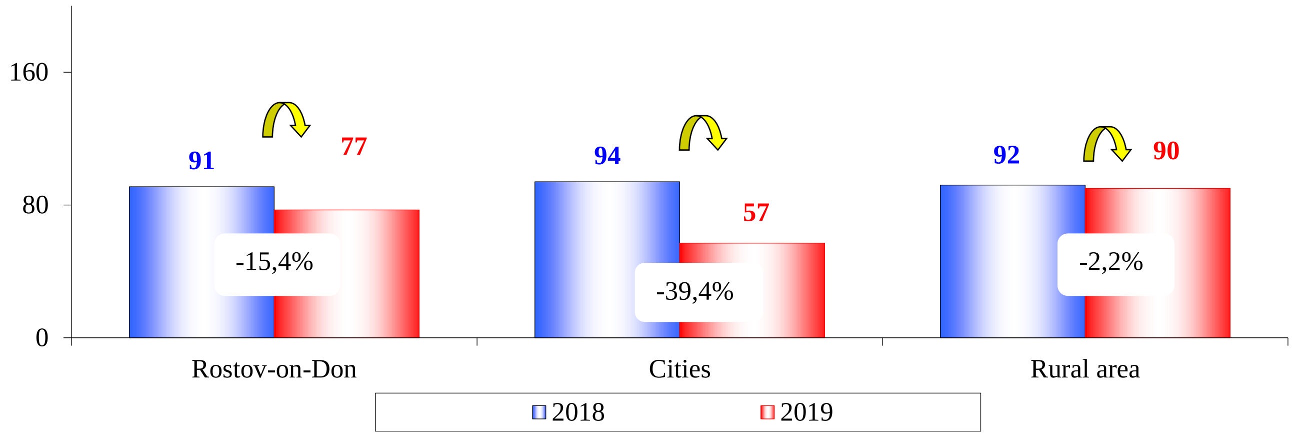

Fig. 3. The number of injured people in fires in the Rostov region

The dynamics of the number of fires decreased in cities, compared to the SPPY by 36.4 %, and in rural areas by 35.2 %. In Rostov-on-Don, the number of fires decreased by 26.1 %.

The increase in the number of people killed in the fire is noted in Rostov-on-Don (+36.0 %), Azov (+50.0 %), Volgodonsk (+500 %), Kamensk-Shakhtinsk (+25.0 %), Novocherkassk (+16.7 %), Novoshakhtinsk (+14.3 %), Azov (+57.2 %), Bagaevskiy (+50.0 %), Sholokhovskiy (+200 %), Kamenskiy (s) (+25.0 %), Martynovskiy (+300 %), M. Kurganskiy (+100 %), Myasnikovskiy (+100 %), Neklinovskiy (+100 %), Orlovskiy (+100 %), Peschanokopskiy (+50.0 %), Remontnenskiy (+100 %), Salskiy (+100 %), Tatsinskiy (+100 %), Tselinskiy (+100 %), Tsimlyanskiy (+100 %) districts of the region (Fig.4).

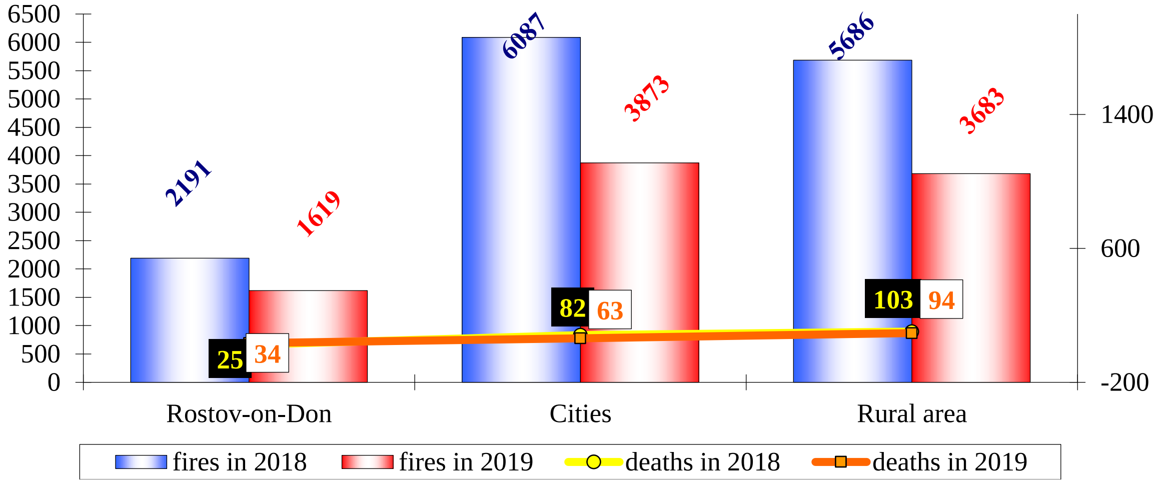

Fig. 4. Number of fires and deaths by region

Among people killed in the fires were men — 74.3 % (SPPY-71.9 %), women — 24.1 % (SPPY — 27.6%) of the total number. Gender was not determined in 1.6 % of the victims (SPPY — 0.5 %) (Table 1). At the same time, 34.6% of people killed in fires were under the influence of alcohol (drugs) (SPPY — 29.5% of the total number of deaths).

Table 1

Distribution of the dead by gender

Gender	Death toll in 2018	Death toll in 2019	% +,–
Male	151	142	–6,0
Female	58	46	–20,7
Gender is not determined	1	3	+200

1.7 % of the total number of victims were aged from 1 to 6 years (SPPY — 4.1 %), 13.0 % — from 20 to 40 years (SPPY — 17.5%), 44.1 % — from 41 to 60 years (SPPY — 38.7%) and 41.2 % — over 60 years (SPPY — 36.1%)

Table 2

Distribution of the dead by age

Age	Death toll in 2018	Death toll in 2019	% +,–
from 1 to 6 years	8	3	-62,5
from 7 to 13 years	4	0	-100
from 14 to 15 years	1	0	-100
from 16 to 19 years	2	0	-100
from 20 to 40 years	34	23	-32,4
from 41 to 60 years	75	78	+4,0
more than 60 years	70	73	+4,3

If we analyze by day of the week, a large number of fires was observed on Sunday — 1494 fires (16.3 % of the total number) and on Monday — 1360 fires (14.8% of the total number). The maximum number of fires was recorded on Wednesday — 1178 fires (12.8 % of the total number).

The highest number of victims (35 people, 18.3% of the total) — on Saturday, the lowest (19 people, 9.9 % of the total) — on Wednesday.

The main time of day when people were killed is evening and night hours. So, in the period from 8 p.m. to 01.59 a.m., 42 people were killed. In total, 118 people (61.8% of the total number) were killed in the period from 20.00 p.m. to 08.00 a.m. (Fig. 5).

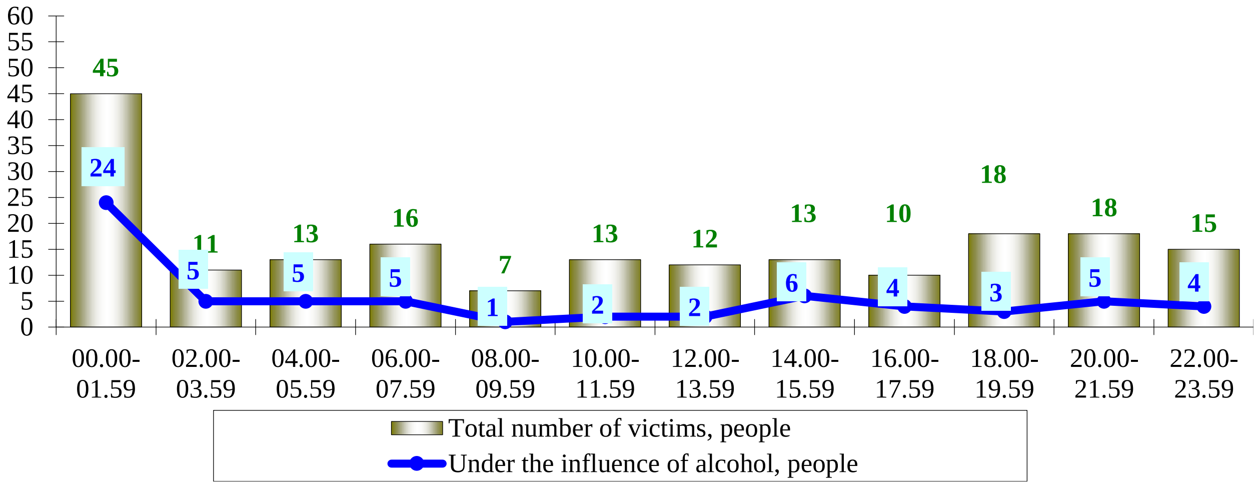

Fig. 5. Number of people killed by time of day

In 2019, there were 3 fires in the Rostov region, as a result of which 3 children died, and in the same period previous year there were 8 fires, the victims of which were 15 children (–80.0% of the SPPY).

The main causes of fires that killed children in 2019 include: careless handling of fire — 2 cases, lack of design and manufacture of electrical equipment — 1 case.

Fires that caused the death of children occurred:

— during the period from 12 to 6 p.m. — 2 cases;

— in the period from 6 to 12 p.m. — 1 case.

In 2019 in the cities of the region there were registered:

— 5492 fires (–59.9 % to SPPY);

— 97 deaths (–9.3 % of the SPPY);

— 134 people injured (–27.6% of the SPPY).

Direct material damage was caused in the amount of 124 million 958 thousand rubles (–3.8 %).

The cities of the Rostov region accounted for:

— 59.9 % of the total number of fires;

— 42.5% of the material damage;

— 50.8 % of the number of people killed in fires;

— 59.8 % of injured people (Fig. 6).

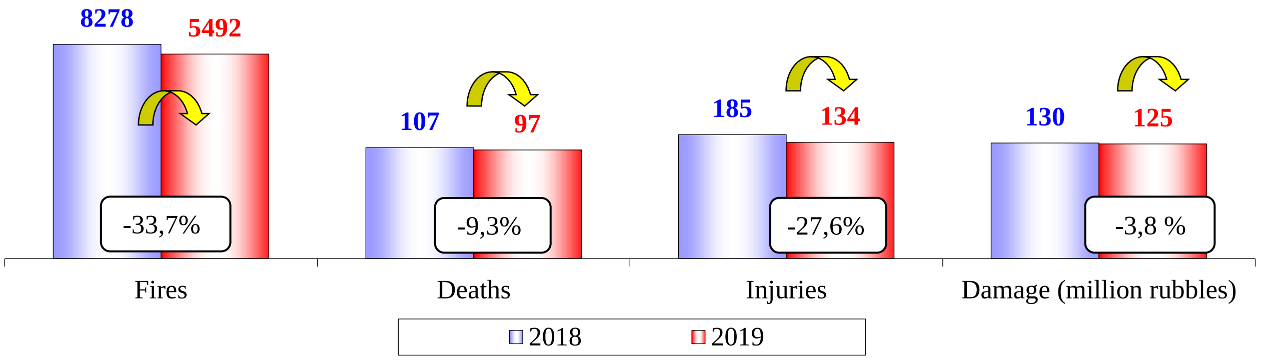

Fig. 6. Number of fires and their consequences in cities

In rural areas of the region there were registered:

— 3683 fires (–35.2 % to APPG);

— 94 deaths (–8.7 %);

— 90 people injured (–2.2 %).

Direct material damage was caused in the amount of 169 million 378 thousand rubles (+44.4 %).

Rural areas accounted for:

— 40.1 % of the total number of fires;

— 57.5 % of the material damage;

— 49.2 % of the number of people killed in fires;

— 40.2 % of injured people (Fig. 7) [10].

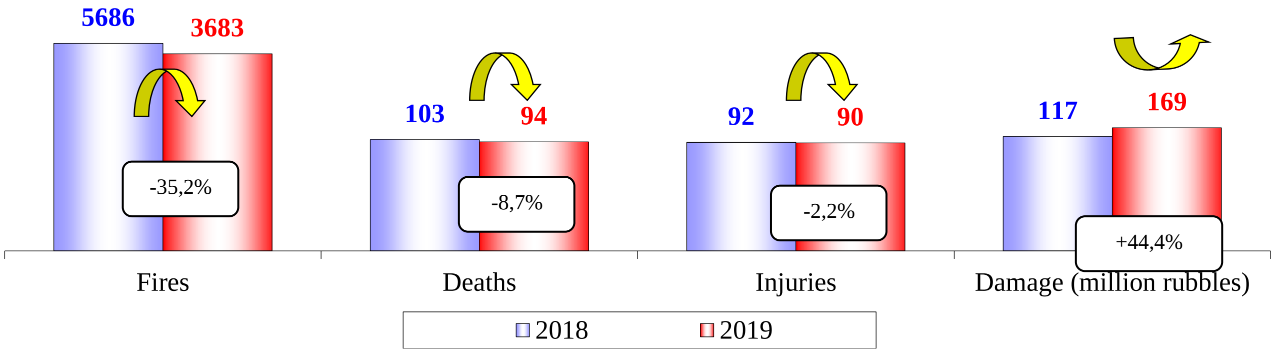

Fig. 7. Number of fires and their consequences in rural areas

In comparison with the SPPY, a decrease in the number of fires was recorded in garden houses (summer houses) (–38.0%), as well as in industrial facilities (–23.9%). There was an increase in the number of fires among motor vehicles (+18.8 %), unused buildings (more than 2 times), warehouse buildings (+40.0%), retail premises (+6.3%) (Fig. 8, table 3).

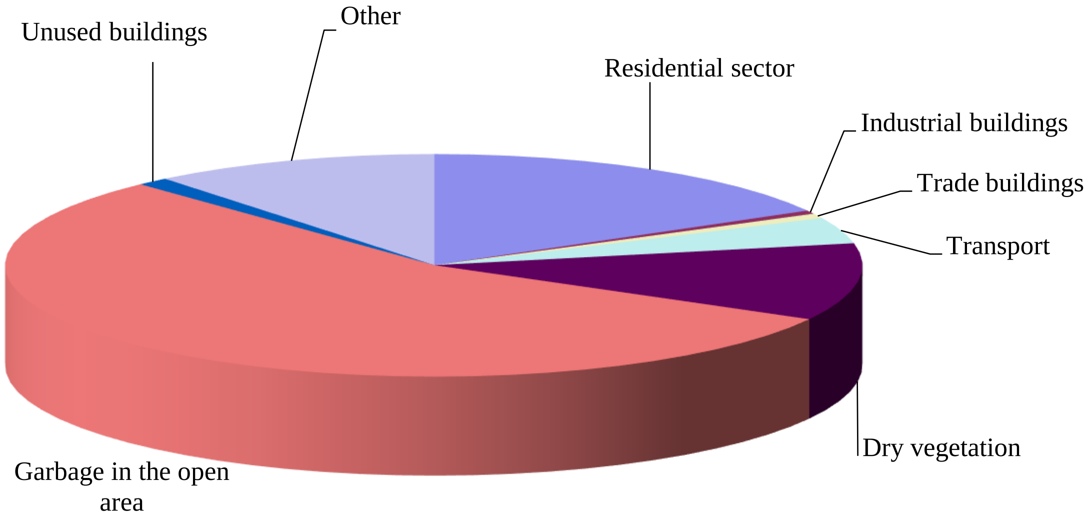

Fig. 8. Distribution of the number of fires by main objects from the total number of fires

Table3

Main objects of fires in comparison with the same period previous year

Fire objects	2018	2019	%	Fire objects	2018	2019	%
Industrial enterprises	55	37	–327	Public institutions	15	15	–
Storage facilities	15	21	+40,0	Dwellings	1539	1543	+0,3
Trading enterprises	64	68	+6,25	Agricultural buildings	7	9	28,6
Educational institutions	5	6	+20,0	Open areas	10510	6145	–41,5
Preschool institutions	2	1	–50,0	Buildings under construction	11	7	–36,4
Cultural organizations	6	6	–	Transport	293	348	+18,8
Medical institutions	2	4	+100	Others	1442	966	–33

Fig. 9 and table 4 show the main causes of fires and the dynamics of changes in their number.

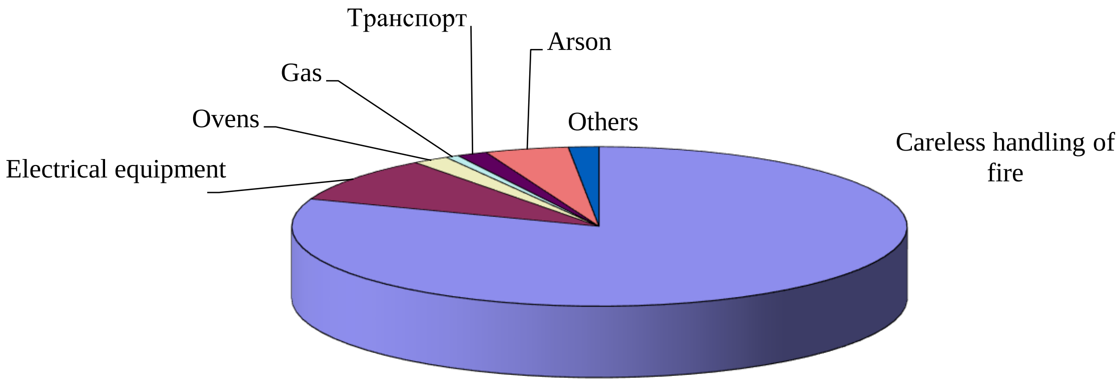

Fig. 9. Distribution of the number of fires according to the main reasons

Table 4

Main reasons of fires in comparison with the same period previous year

Cause of fire	2018	2019	%	Cause of fire	2018	2019	**%**
Arsons	373	407	+9,1	Careless handling of fire	653	7338	in 11 times
Disregard for the rules of electrical equipment safe operation	790	840	+6,3	Children play with fire	41	51	+24,4
Disregard for the rules of heat generator safe operation	10	22	in 2 times	Disregard for the rules of transport safe operation	113	147	+30,1
Disregard for the rules of ovens safe operation	183	152	–16,9	Disregard for the rules of safe operation when welding or machining metals	18	13	–27,8
Disregard for the rules of gas equipment safe operation	60	63	+5,0	Other reasons	121	142	–17,4

In relative terms, the situation with fires in the Rostov region in 2019 can be described as follows:

— the number of fires per 100 thousand people — 216.4 (34.3 % less than in the SPPY), for 2018 — 329.3 (the average figure for the Southern Federal District was 279.07 and for the Russian Federation — 320.72);

— the number of fire victims per 100 thousand people — 4.5 (10.0 % less than in the SPPY), for 2018 — 5.0 (the average figure for the Southern Federal District was 4.71 and for the Russian Federation — 5.79);

— average damage from a single fire — 32.1 thousand rubles (+80.3 %), for the SPPY 2018 — 17.8 thousand rubles (the average figure for the Southern Federal District was 22.54 and for the Russian Federation — 28.87).

— the number of people injured in fires per 100 thousand people — 5.3 (18.5 % less than in the SPPY), in 2018 — 6.5 (the average figure for the Southern Federal District was 4.76 and for the Russian Federation — 6.45).

Figure 10 shows the excess of 21.7 in the average number of fires (per 10 thousand population) in 28 cities and districts of the region. The values of the indicators are above the "red" line.

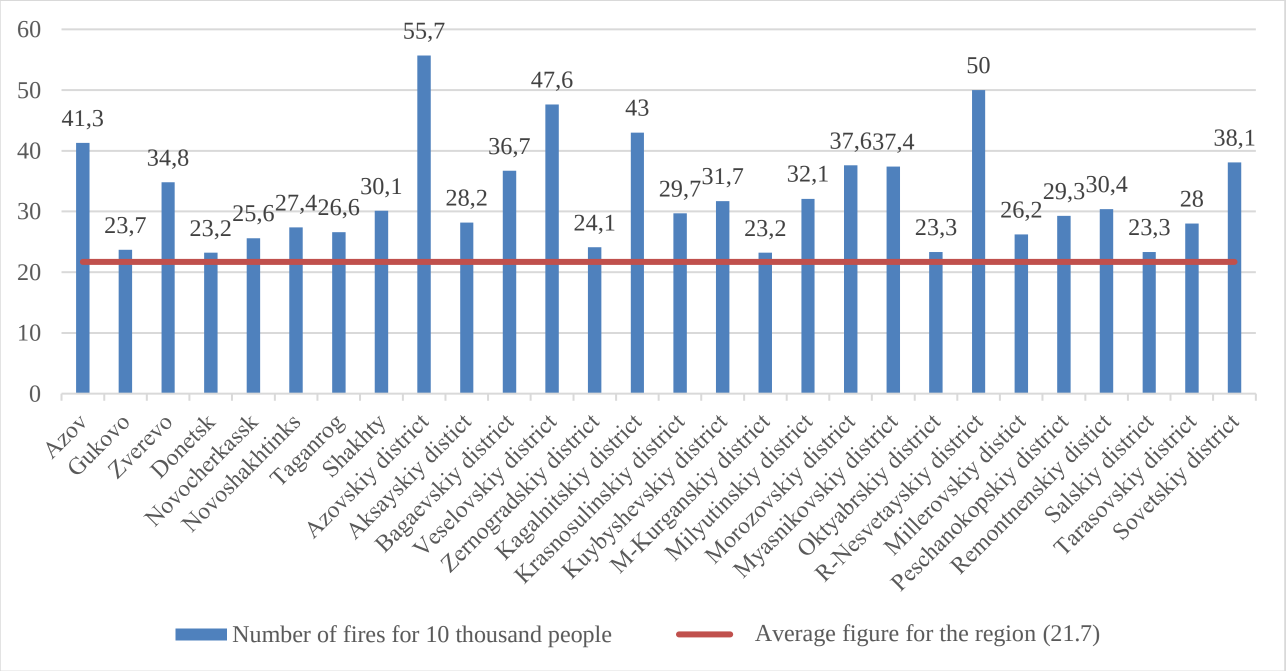

Fig. 10. The number of fires per 10 thousand people

Figure 11 shows an excess of 0.5 in the average number of people killed in fires (per 10 thousand people) in 26 cities and districts of the region. The values of the indicators are above the "red" line.

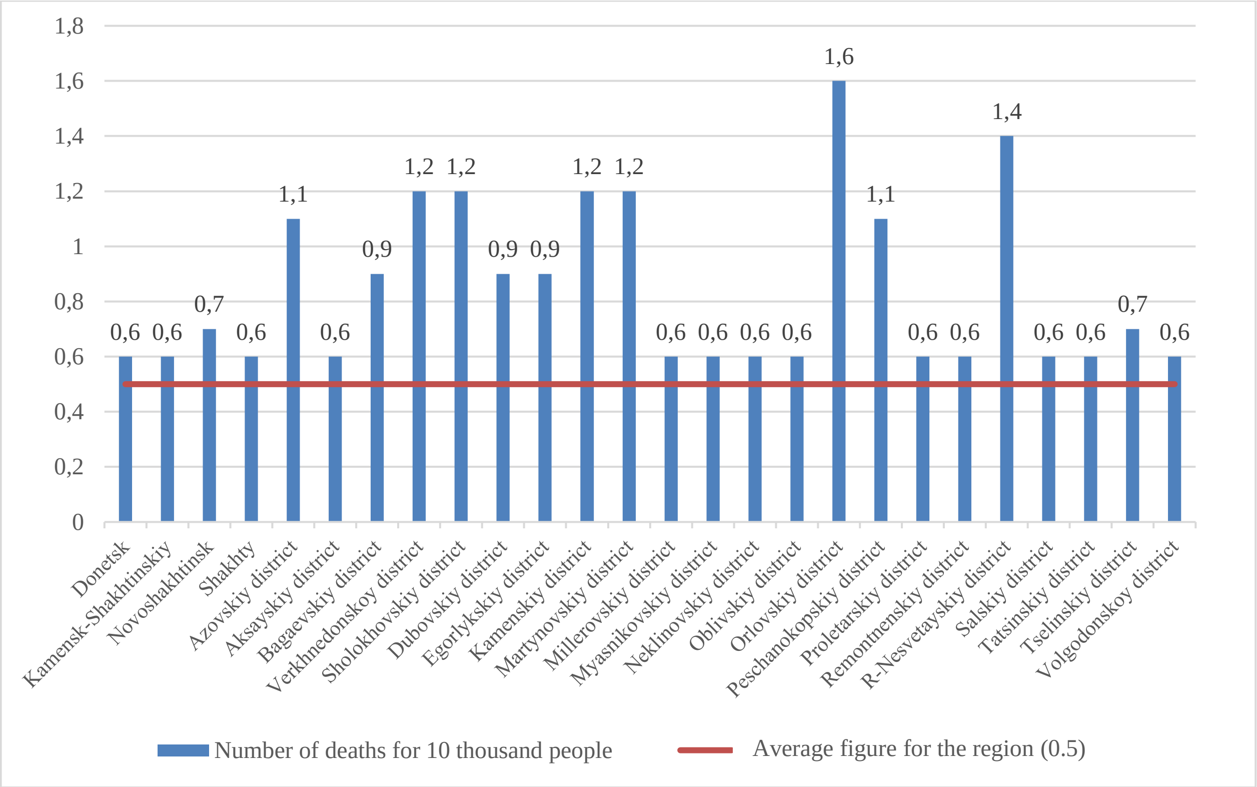

Fig. 11. The number of people killed in fires per 10 thousand people

Figure 12 shows an excess of 0.5 in the average number of injured people in fires (per 10 thousand people) in 21 cities and districts of the region. The values of the indicators are above the "red" line.

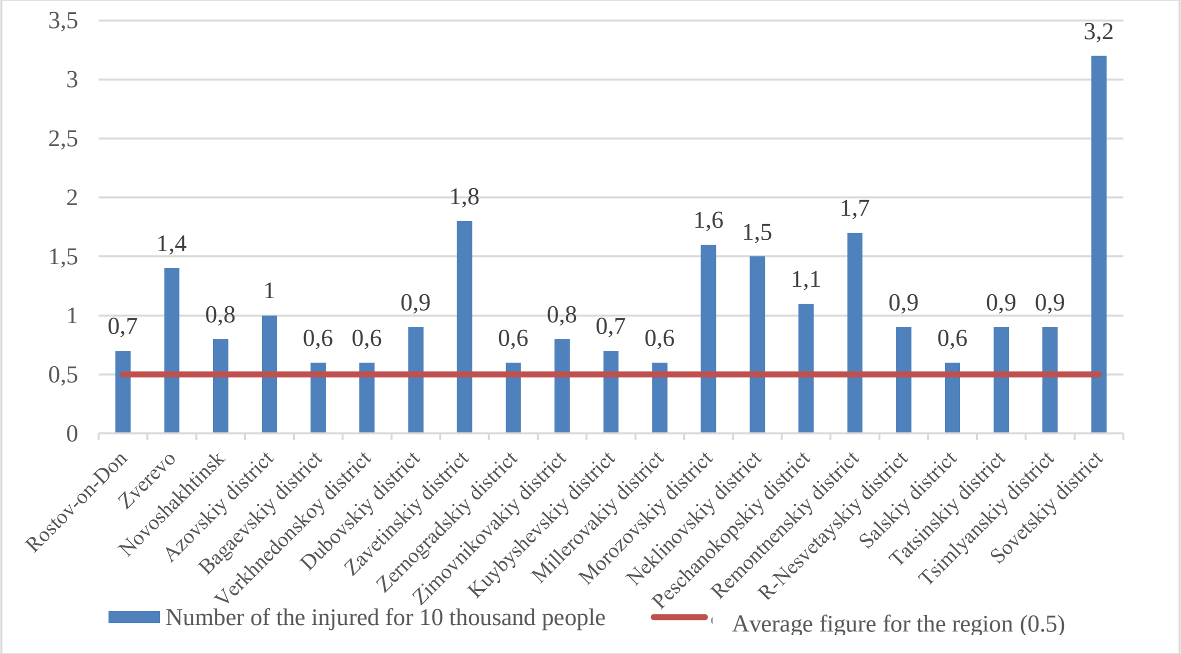

Fig. 12. The number injured in fires per 10 thousand people

Conclusions. The analysis of fire statistics in the Rostov region for 2018-2019 is based on the official data of the Ministry of Emergency Situations of Russia for the Rostov region, which indicates the reliability of the information provided.

Statistical data were evaluated based on key factors affecting fire safety: the number of fires in the Rostov region, days of the week, and months; the number of people injured and killed in fires and their distribution by gender, age, and time of death; objects and causes of fires.

As a result, a number of critical factors and conditions have been established, under which the risk of death and injury in fires is maximum:

— the average risk of death in a fire in the Rostov region is 5×10-5 people/year, but there are areas where it is 3-6 times higher and does not correspond to the acceptable indicator in Russia (Orlovskiy, Azovskiy and Rodionovo-Nesvetayskiy districts);

— cities in the region take the first place in the number of fires compared to rural settlements and their growth is observed;

— most often, garbage burns in an open area, and fires occur in the residential sector;

— the largest number of fires among objects in the Rostov region occurs at industrial and commercial enterprises;

— August and September are the traditional months of the year with the highest number of fires;

— there are cases of death and injury in a fire on Saturday and Monday, most often during the week, as well as in the evening and at night;

— men die approximately 3 times more often than women in fires;

— the highest number of people killed and injured in a fire is among people aged 41-60 years and 60+.

The main causes of fires in the region are the following:

— disregard for the rules of installation and operation of electrical equipment;

— arsons;

— disregard for the rules of safe operation of furnaces.

Consequences of the negative impact of fires are directly related to the amount of material damage. So in 2019, in the cities of the region, direct material damage was established in the amount of 124 million 958 thousand rubles, and in rural areas, direct material damage amounted to 169 million 378 thousand rubles.

In comparison, in 2019, in Russia as a whole, material damage from fires was 18.2 billion rubles. Compared to the previous year, the amount of material damage increased by 17.1 %. Every day, approximately 1,292 fires occur in the country, in which 23 people are killed, 26 people are injured, and the daily damage amounts to 49.8 million rubles.

Such significant material and human losses make us look for ways to quickly implement new effective fire control measures.

Here is a description of the most promising and popular firefighting measures at the moment.

1. Technologies with artificial intelligence (AI) help us study in detail large amounts of geospatial, meteorological and temporal data to predict the occurrence of fires. AI involves the use of compact sensors that collect information about heat bursts, as well as changes in the illumination of the area. Then the data stored in the cloud is visualized using AI and used to create special temperature maps. These maps are designed to identify critical areas where the temperature is most likely to exceed the permissible limits, as well as areas with the greatest amplitude of temperature fluctuations. All this helps us understand which regions are most at risk, where a fire may occur.

2. Robotic fire extinguishing systems that have the means to register the location of the source of fire by video monitoring. They are effective for eliminating fires of any severity with heavy smoke and high temperatures. In addition to permanently installed robots, the Ministry of Emergency Situations of the Russian Federation uses self-propelled and flying unmanned devices that can perform reconnaissance and rescue people from the fire zone.

3. New fire extinguishing agents for public buildings, such as refrigerants, the main advantage of which is high heat absorption and temperature reduction (up to 70 %). These properties allow not only to quickly eliminate the source of the fire, but also to gain additional time for evacuation.

4. Control and supervision activities — one of the classic effective fire control measures, which also uses new ideas related to the introduction of checklists (lists of control questions) during routine inspections. The idea is that the examiner and the examinee are on an equal footing. The list of control questions is exhaustive. The entrepreneur knows in advance the requirements imposed on him. The inspector is not given the right to check compliance with other security requirements. This makes it possible to simplify supervisory procedures as much as possible, providing an opportunity for self-monitoring and self-assessment of the security status of objects to their owners.

To prevent fires in houses in the region, there are operational groups of representatives of municipalities, senior localities, street and house committees, freelance fire instructors, public associations (volunteers, Cossacks, All-Russian Voluntary Fire Organization, etc.), representatives of the Ministry of Internal Affairs and employees of the Ministry of Emergency Situations of Russia.

As part of preventive measures, more than 3 thousand yard rounds, meetings and briefings with the population are held daily in the region.

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Submitted 19.05.2020
Scheduled in the issue 10.07.2020

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Contribution of the authors:

V. G. Ustin — access to official fire statistics; Yu. I. Bulygin — formulation of the main concept, goals and objectives of the study, analysis of the results of the study; P. P. Tretyakov — collection of statistical data on fires, refinement of the text, formulation of the conclusions; V. V. Maslensky — preparation of the text and diagrams.

UDC 629.3.012 https://doi.org/10.23947/2541-9129-2020-3-33-38

Evaluation of safety parameters of the motor grader during maneuvering in the street and road network

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Introduction. The article is devoted to improving the safety of operation of motor graders in urban conditions. The paper considers analytical methods for evaluating the influence of structural, geometric and kinematic characteristics of the motor grader on the safety of maneuvering in urban conditions for u-turns and turns at the intersections of the road network.

Problem Statement. In the course of the study, it is necessary to establish safe values of kinematic and geometric parameters for maneuvering of motor graders with articulated frames in urban conditions.

Theoretical Part. The numerical estimates were made based on the technical characteristics of three types of articulated frame graders. We consider possible options for moving the grader out of the street or roadway when making a "right" or "left" turn at a road intersection to avoid the situation of moving the grader out of the street or roadway. The calculation scheme for determining the parameters of the motor grader's turn is constructed.

The calculation formulas for the external and internal overall turning radii of the grader and the overall traffic corridor are obtained. This allows you to determine the minimum width of the roadway for safe maneuvering of the motor grader. The value of the required safe minimum turning radius of the motor grader for a given width of the roadway is determined. All calculation formulas are obtained for the general case when the trajectories of the rear and front wheels do not coincide. It is shown that when turning the motor grader, the most dangerous is the radius of the front dimensions, determined by the extreme points of the front bulldozer blade. The radius of the rear dimensions in this case can be ignored, because it is of negligible importance. If you make a u-turn at an intersection, you can take the grader blade out of the roadway. The maximum radius is determined by the size of the blade that goes beyond the width of the grader.

Conclusion. The obtained solutions can be used to determine safe maneuvering modes for motor graders in urban conditions.

Keywords: motor grader, maneuverability, radius of turn, rotatability.

For citation*:* Deryushev V. V., Kosenko E. E., Kosenko V. V. Evaluation of safety parameters of the motor grader during maneuvering in the street and road network: Safety of Technogenic and Natural Systems. 2020;3: 33‒38. https://doi.org/10.23947/2541-9129-2020-3-33-38

Introduction. When operating construction and utility vehicles in urban environments, the key factor in ensuring safety is maneuvering at intersections with different street widths, in driveways of a given shape and size, as well as on limited areas of the support surface. Road safety in these conditions is determined by the maneuverability properties of wheeled vehicles, one of which is motor graders. The work [1] is devoted to the study of the issues of motor grader maneuverability, and the issues of reliability of equipment operation are covered in [2-4]. A lot of research has been devoted to determining the maneuverability properties of wheeled vehicles, and the main results are fixed in the normative technical documentation. However, the calculation formulas given there are obtained, as a rule, for cases of maneuvering on unlimited areas of the support surface and under the condition that the wheels of the rear and front axles move along the same trajectory. In general, these conditions are not met.

Problem statement. The main purpose of these studies is to establish safe values of kinematic and geometric parameters for motor graders maneuvering in urban conditions. To achieve this goal, you need to solve the following two tasks:

1. Set all possible options for grader leaving the roadway, related to its location on the roadway, when performing a u-turn, right turn at the intersection of roads (with two-way or one-way traffic), exit (removal of the front

left dimensions) on the oncoming lane, turn (removal of the right dimensions) on the sidewalk, as well as the removal of the rear left dimensions on the adjacent lane.

2. Determine what turning radius a grader with the specified length and width should have when making a right turn at the intersection of roads with the specified width of streets (with two-way or one-way traffic), in order to avoid the above-mentioned situations of the grader leaving the borders of the occupied lane and roadway.

Materials and methods. To solve these problems, a calculation scheme is constructed to determine the parameters of the turnability of a grader with an articulated frame (Fig. 1).

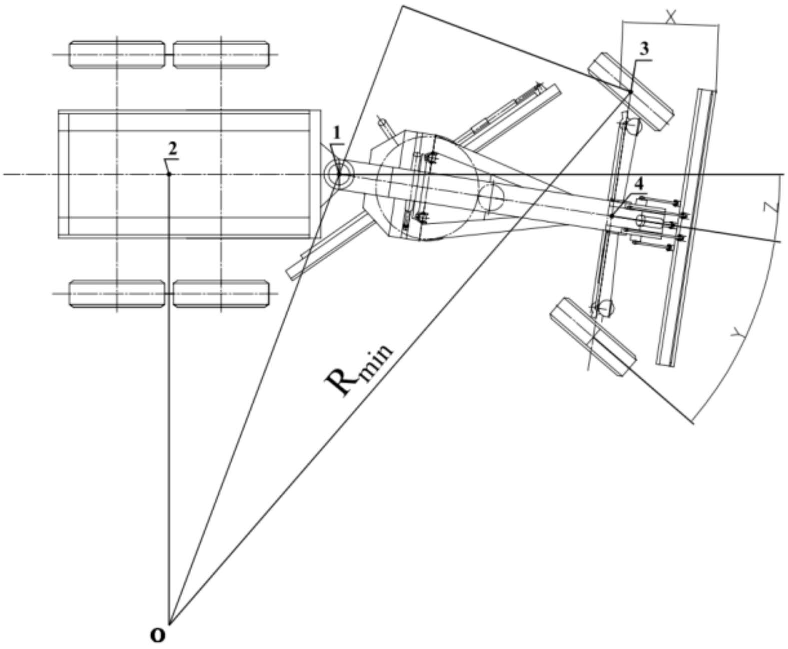

Fig. 1. Calculation model of the motor grader's turnability

In the diagram, point O is the center of rotation (GOST 27257-87 or ISO 7457-83), the point around which the rotation of a constant radius is performed. The center of rotation is determined as the point formed by the intersection of the line 0-2 (perpendicular to the longitudinal axis of the grader, passing through the middle of the rear cart with the driving axles) and the line 0-3 (perpendicular to the plane of rotation of the most remote controlled wheel).

R_{min} — the minimum turning radius (half of the minimum turning diameter according to GOST 27257-87), it is defined as the distance from the center of the turn to the center of contact of the tire with the support surface when the machine performs a steeper turn (i.e., at the maximum angle of the turn of the controlled wheels Y and the articulated frame Z in Fig. 1). Theoretically, R_{min} is determined by the following formula:

$$R_{min} \approx \frac{(1-2)+(1-4)\cdot cosZ}{\sin(Z+Y)}. \qquad (1)$$

Theoretical part. The example of calculation of turnability parameters. Let the joint divide the base of the grader in the ratio 1/3. Then for the motor grader (I) we get:

segment 1-2 = 2000 mm,
segment 1-4 = 4000 mm,
angle Z_{max} = 22°,
angle Y_{max} = 40°.

$$R_{min} = \frac{2000+4005\cdot cos22°}{\sin(40°+22°)} = \frac{2000+4005\cdot 0{,}927}{0{,}883} = \frac{5708}{0{,}883} = 6470 \text{ mm.} \qquad (2)$$

If there is no turn of the articulated frame (angle Z = 0)

$$R_{min} = \frac{6005}{\sin 40°} = \frac{6005}{0{,}643} = 9339 \text{ mm.} \qquad (3)$$

To determine the turning radius that a grader should have when making a right or left turn at an intersection with a given width of streets (or roadway), in order to avoid the situation of the grader leaving the lines of streets or roadway, it is necessary to determine the overall traffic corridor. In this case, the overall corridor of $H_{\text{Г}}$ movement is determined as the difference between the outer overall turning radius and the inner overall turning radius [5-9].

Research result. Determination of different turning radii. Let us determine the overall turning radius (external). This is the distance from the center of the turn to the outermost point of the projection of the machine and its working equipment when performing a turn with a minimum radius (according to GOST 27257-87). Let us denote this radius $R_{\text{гн}}$. Under these conditions, it is determined by the right turn of the grader as the left extreme point of the front bulldozer blade, located at X distance from the front axle. .

Then:

$$R_{\text{гн}}=R_{min}+X\cdot\sin Z. \qquad (4)$$

In this case, for the motor grader (I):

$$R_{\text{гн}}=6470+1240\cdot\sin 22°= 6470+1240\cdot 0{,}375 = 6935 \text{ mm}. \qquad (5)$$

Let us determine the internal turning radius of the tires (according to GOST 27257-87) or the internal overall radius, which is designated $R_{\text{гв}}$.

It is determined by the formula

$$R_{\text{гв}} = R_{min}\cdot\cos (Z+Y) + (1\text{-}4)\cdot\sin Z – B. \qquad (6)$$

In this case, for the motor grader (I):

$$R_{\text{гв}} = 6470\cdot\cos (40° + 22°) + 4005\cdot\sin 22° – 2500 = 2043 \text{ mm}. \qquad (7)$$

Then the overall traffic lane of the grader ($H_{\text{г}}$) at the maximum sharp turn with the minimum radius is equal to:

$$H_{\text{г}} = R_{\text{гн}} – R_{\text{гв}} = R_{min} + X\cdot\sin Z – R_{min}\cdot\cos (Z+Y) – (1\text{-}4)\cdot\sin Z+B. \qquad (8)$$

Or after conversions

$$H_{\text{г}} = R_{min}\,(1 – \cos (Z+Y)) – ((1\text{-}4) –X)\cdot\sin Z + B. \qquad (9)$$

For the motor grader (I):

$$H_{\text{г}} = 6470\ (1 – 0{,}47) – (4005 – 1240)\cdot 0{,}375 + 2500 = 4892 \text{ mm}. \qquad (10)$$

When making a right or left turn, the overall traffic lane must fit into the specified width of the street for one-way traffic or the permitted traffic lane for two-way traffic, as shown in Fig. 2 [10-11].

In this case, the minimum width of a one-way street (the width of the $S_{\text{пч}}$ roadway) is:

$$S_{\text{пч}} = R_{\text{гн}} – R_{\text{гв}}\cdot\cos 45°. \qquad (11)$$

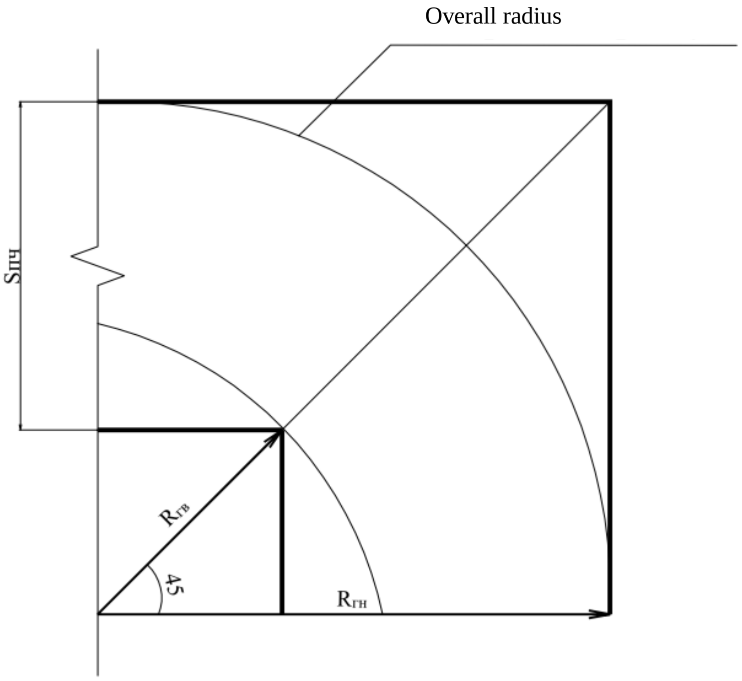

Fig. 2. Internal ($R_{\text{гв}}$) and external ($R_{\text{гн}}$) overall radii of the motor grader

For the motor grader (I):

$$S_{\text{пч}} = 6935 – 2043\cdot 0{,}707 = 5491 \text{ mm}. \qquad (12)$$

That is, if the width of the street (roadway) $S_{\text{пч}}$ is less than 5820 mm (for example, if the specified width is 3 m, 4 m, 5 m), it is theoretically impossible to turn the motor grader (I) without leaving or moving the dimensions outside the permitted lane.

If the roadway width ($S_{пч}$) is set, the required minimum turning radius R_{min} is determined after converting the following expression:

$$S_{пч} = R_{min} + X \cdot \sin Z - (R_{min} \cdot \cos(Z+Y) + (1\text{-}4) \cdot \sin Z - B) \cdot \cos 45. \quad (13)$$

As a result, we get:

$$R_{min} = \frac{S_{пч} + \left((1-4) \cdot cos45° - X\right) \cdot sinZ - B \cdot cos45°}{1 - \cos(Z+Y) \cdot cos45°}. \quad (14)$$

The results of calculations for three types of motor graders are summarized in Tables 1-3.

Table 1

Minimum rotation radius of the motor graider

	1-4	Z_{max}	Y_{max}	R_{min} (mm)	
				when folded	without folding
Grader (I)	4005	22°	40°	6470	9339
Grader	4240	23°	40°	6623	9705
Grader	4320	25°	45°	6298	8939

Table 2

Overall radii and minimum street width

	$R_{гн}$ (mm)	$R_{гв}$(mm)	$H_г$(mm)	$S_{пч}$(mm)
Grader (I)	6935	2043	4892	5491
Grader (II)	7150	2134	5016	5641
Grader (III)	6868	1447	5421	5845

Table 3

Required minimum rotation radii R_{min} (mm)

Street width	6 m	7 m	8 m	9 m
Grader (I)	7231	8729	10226	11724
Grader (II)	7185	8658	10131	11605
Grader (III)	6507	7827	9147	10466

The calculations do not consider the case when the trajectory of the rear and front wheels is the same. In this case, the grader's turnability parameters will be worse.

As a result of the calculations, it was found that the minimum turning radii of the graders are 6470, 6623, 6298 mm, respectively, while the smallest width of the roadway should be 5491, 5641, 5845 mm. R_{min} can be reduced by 10% to guarantee the grader passage.

Conclusion. After analyzing the possible options of going beyond the boundaries of the roadway of the grader associated with its location on the roadway for turn, right turn at the crossroads (with one-way or two-way movement), moving (take-out front left dimensions) into the oncoming lane, hitting (the removal of the right dimensions), etc., experts say that a turn of the grader is carried out with all the wheels on the roadway. In this case, the removal of the front dimensions is most likely, determined by the extreme points of the front bulldozer blade. The value of the dangerous radius is Xsin Z (465, 528, 571 mm). The removal of the rear dimensions in this case can not be taken into account, because it is of negligible importance. If you make a sharp turn at an intersection, the grader blade can be removed from the roadway (Fig. 2). The maximum removal is determined by the size of the blade that goes beyond the width of the grader. Thus, the tasks set in this paper are solved, and the obtained analytical expressions can be used in the analysis of the safety of maneuvering of wheeled vehicles in urban conditions.

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Submitted 15.05.2020
Scheduled in the issue 01.07.2020

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V. V. Deryushev — main concept formulation, goals and objectives of the research; E. E. Kosenko — calculations, preparation of the text, conclusions; V. V. Kosenko — research results analysis, text refinement, correction of the conclusions.

UDC 622.692.4 https://doi.org/10.23947/2541-9129-2020-3-39-46

Problems of corrosion protection during safe operation of pipeline systems and equipment of oil and gas industry

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Introduction. Organization of safety hydrocarbons transportation is one of the primary objectives for companies operating hazardous production facilities. Corrosion protection of field pipelines is still the most complex and multifaceted task. That is due to significant length of communication lines, branching pipeline networks, complex and heterogeneous composition of pumped liquids.

Problem Statement. The purpose of this research is the development of method of salinity control and the prevention of premature corrosion wear of oil pipelines by the use of inhibitors.

Theoretical Part. When transporting oil and petroleum products through pipelines, there is a high probability of synergistic risks arising from corrosion of the pipeline body material, including salt deposits. Salt formation affects the throughput, performance of pipeline systems, and equipment performance.

According to the result of in-line diagnostics analysis, more than 70% of pipes are subject to corrosion, with metal loss and changes in wall thickness. Corrosion also led to metal properties transformation, and degradation of its functional characteristics. Inhibitors are widely used during oil production and transportation to protect from the formation of salt deposits. With long-term operation of oil and gas pipelines it is not possible to ensure completely safe operation. Pipeline systems are constantly affected by the environment, external and internal pressure, corrosion and aging of the pipeline material.

Conclusion. The article presents a brief overview of the current state of oil pipelines, and a new method for protection from salt deposits. The composition of the salt deposition inhibitor, including citric acid, has been developed. It has been experimentally established that its use reduces the number of accidents. A brief analysis of the occurrence of accidents in the oil and gas industry is performed. The problems of safe operation of pipeline systems under the influence of non-stationary factors are determined. The necessity of creating a method for mathematical modeling of pipeline systems is confirmed.

***Keywords**:* oil and gas pipelines, corrosion, citric acid, reduction of technology related risks, salt deposits, corrosion inhibitors, nonstationery risks, operational safety.

For citation: Abdrakhmanova K. N., Dyagilev I. A., Abdrakhmanov N. Kh., Shaybakov R. A. Problems of corrosion protection during safe operation of pipeline systems and equipment of oil and gas industry: Safety of Technogenic and Natural Systems. 2020;3: 39–46. https://doi.org/10.23947/2541-9129-2020-3-39-46

Introduction. An urgent task in the operation of oil and gas pipelines is to protect pipes and equipment from corrosion. It is impossible to completely exclude corrosion phenomena, but it is possible to take timely measures for anticorrosion protection.

The most difficult issues remain protection from corrosion of field pipelines. In particular this is due to:

— significant length of communications,

— branching of pipeline networks,

— complex and heterogeneous composition of the pumped liquids,

— soil characteristics in the pipeline sections [1-3].

Salt deposition reduces safety of operation of the pipeline systems intended for transportation of hydrocarbons. This determines the relevance of the work. Processes of oil or gas extraction and transportation are often accompanied by undesirable formation of deposits of inorganic salts on the walls of the equipment and associated reservoirs. As pumping volumes increase, so do deposits.

The use of new technological and technical solutions for the transportation of flammable and combustible substances allows us to establish a higher level of industrial and fire safety of the operated dangerous object. This problem has been studied by many Russian and foreign authors [4-6].

Ensuring safe transportation of hydrocarbon media is one of the main tasks of organizations operating hazardous production facilities. The diagnostics of 600 technological and oilfield pipelines revealed unacceptable defects in 75 % of cases [7, 8].

Problem statement. The aim of this study is to develop a method for controlling salt deposition and preventing premature corrosion wear of oil pipelines by introducing inhibitors. Salt deposition on the walls of field pipelines affects their throughput and productivity. Salt formation is also one of the causes of metal corrosion. Therefore, to control salt deposition and prevent premature wear in the oil fields, inhibitors are introduced into the field pipeline system.

Theoretical part. The analysis of the pipeline diagnostics results of the main pipelines shows that the proportion of pipes with defects ranges from 9.6 to 21.8 % (indicators depend on the pipeline section, the presence of welds and shut-off valves). The percentage of pipes with dangerous defects is from 0.5 to 3.7 %. Of these, about 70% are pipes with metal losses and changes in wall thickness, including corrosion. During corrosion, the properties of the metal change and its functional characteristics deteriorate [9, 10]. One of the factors influencing the indicators of metal corrosion and wear is salt formation [11].

The safety of pipeline operation depends, in particular, on the pressure and physical and chemical properties of the pumped medium.

Accidents often occur due to aging of pipeline systems [12, 13]. It is not always possible to use well-known methods of in-line diagnostics to find out the cause of dangerous defects, measure them, and set the maximum value of the equipment's service life.

The difficulties of in-line diagnostics are caused by changes in cross-sections in pipeline systems and the formation of local resistances.

Salt deposition on the walls of pipelines affects the throughput, the performance of pipeline systems and the equipment operability, including those with moving parts.

Salt deposition and its consequences should also be taken into account when using a non-stationary system risk management system.

The introduction of inhibitors is widely used in oil fields and oil treatment sites in order to minimize the formation of salt deposits [14, 15].

The issues of salt deposition control and prevention of premature wear of oil pipelines were solved experimentally: the potential of a previously developed salt deposition inhibitor with the addition of citric acid was evaluated.

Experiment and results. The purpose of the laboratory experiment was to determine the effectiveness of the salt deposition inhibitor SNPKH 5312 grade C of different concentrations with the addition of citric acid. In the experiments, the reservoir water of modular cluster pump station (MCPS) of the oil treatment plant (OTP) of Bayteks LLC was used.

The samples were prepared in seven stages.

1. Seven conical flasks (250 ml) were filled with 100 ml of brine water.

2. In five of them, a salt deposition inhibitor with citric acid (CA, 0.3 mg) was added at concentrations of 10, 20, 30, 60 and 100 mg/dm^3, which corresponds to 0.2; 0.4; 0.6; 1.2 and 2.0 ml of the solution (table 1).

Table 1

Samples of reservoir water of MCPS OTP Bayteks LLC with the concentration of the corrosion inhibitor

Initial solution	No. 1	No. 2 (+ иinhibitor / + CA)	No. 3 (+ иinhibitor / + CA)	No. 4 (+ иinhibitor / + CA)	No.5 (+ иinhibitor / + CA)	No. 6 (+ иinhibitor / + CA)
Without temperature control	Brine water	0.2 mg /0.3 mg	0.4 mg /0.3 mg	0.6 mg /0.3 mg	1.2 mg /0.3 mg	2.0 mg /0.3 mg

3. The flasks were closed with lids. The first flask was a control one, it was not affected.

4. The remaining flasks were thermostated in the Memmert chamber drier at a temperature of 75 °C for 5 hours.

5. After 5 hours, the samples were cooled and filtered through a dense "blue ribbon" filter.

6. To determine the content of calcium ions in conical flasks, 10 ml of filtrate was selected with a Mohr pipette and 40 ml of distilled water was added.

7. Using murexide for Trilon B, the calcium hardness was determined (Table 2).

Table 2

The content of calcium ions in the reservoir water of BKNS UPN LLC Baytex with the addition of a salt decomposition inhibitor SNPH 5312 grade C and citric acid

	Initial sample	Sample no. 1	Sample no. 2	Sample no. 3	Sample no. 4	Sample no. 5	Sample no. 6
V_T^*, ml	12.94	11.76	12.04	12.2	11.8	12.3	12.08
X, ml×g/dm^3	1296.588	1178.352	1206.408	1222.4	1182.36	1232.46	1210.416
*T — titration. X — the content of calcium ions after titration.							

The results of calculating the effectiveness of the salt deposition inhibitor in brine water with the addition of citric acid are shown in Table 3.

Table 3

Effectiveness of the salt deposition inhibitor in brine water of BKNS UPN LLC Baytex with the addition of citric acid

	+ Inhibitor / + CA				
	0.2 mg / 0.3 mg	0.4 mg / 0.3 mg	0.6 mg / 0.3 mg	1.2 mg / 0.3 mg	2.0 mg / 0.3 mg
Effectiveness of the salt deposition inhibitor (ESDI,%)	93	71	85	58	54

The effectiveness of the salt deposition inhibitor (ESDI,%) is determined by the formula (1):

$$Э = (Cp – Cx / Co – Cx)\ 100, \qquad (1)$$

where Cx — is the content of calcium ions in the sample without an inhibitor, mg/dm^3; Cp — is the content of calcium ions in the sample with an inhibitor after temperature control, mg/dm^3; Co — is the content of calcium ions in the initial solution, mg/dm^3.

The experiment and calculations showed that the inhibitor of SNPKH 5312 brand C with citric acid (3 %) effectively prevents the formation of salts in the technical devices of the Baytuganskoye field.

Measures to prevent accidents. The acute problem of corrosion of pipeline systems intended for transportation of hydrocarbon media requires high-quality and cost-effective solutions [16-19].

In this study, cases of ingress of pumped products into the external environment due to depressurization and damage to pipeline systems are considered. Their main reasons:

— uncontrolled metal corrosion of the inner and outer shell of the pipeline,

— hydro-and gas-abrasive wear,

— fatigue and aging of the metal.

The domestic level of technical support for pipeline systems with automation tools and high-quality materials lags behind the world level by 15-20 years [20, 21]. The material, diameter and thickness of the pipes do not always meet the design requirements. There are other reasons that affect the frequency of accidents and incidents in the operation of pipeline systems.

Figure 1 shows data on accidents at oil and gas industry enterprises in the Russian Federation in 2009-2017 [11].

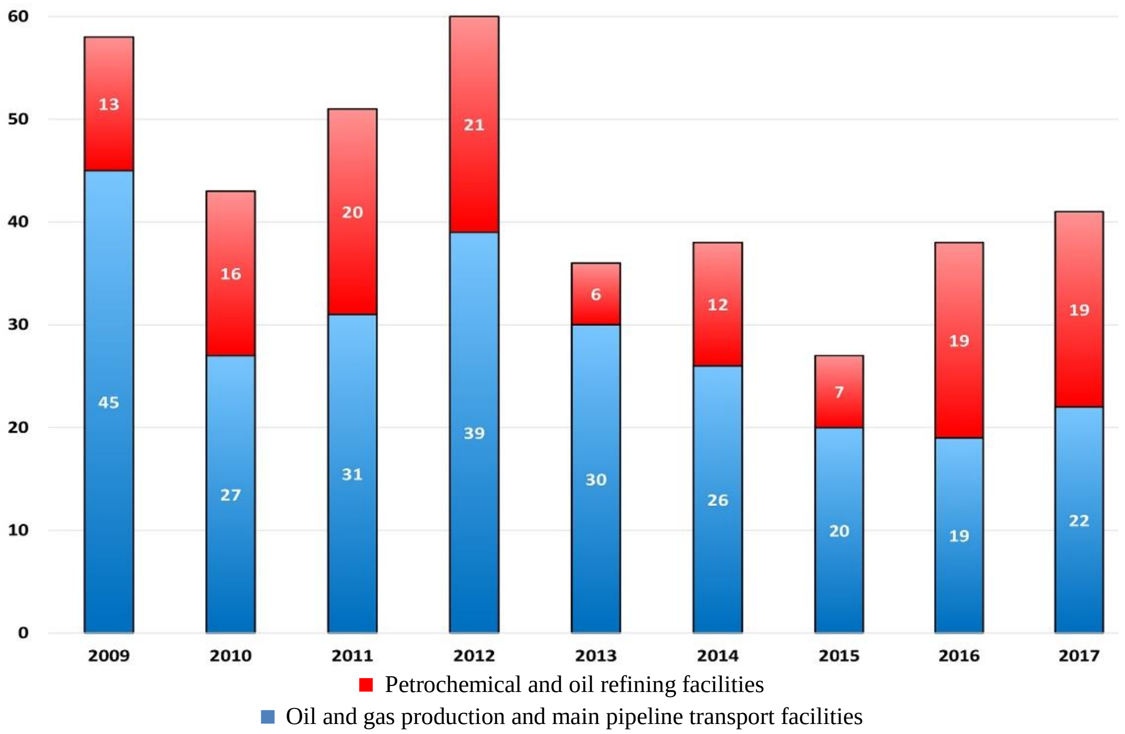

Fig. 1. Dynamics of accidents at the enterprises of oil and gas industry and oil and gas processing

With general patterns of accidents, each has its own distinctive features:

— time of origin and development,

— scale (depends on the energy potential of the equipment)

— pressure that leads to the destruction of technical devices and systems,

— explosions and fires

— release of substances that negatively affect the environment.

In view of the above mentioned, the following tasks are relevant:

— to determine the requirements for the formation of a methodology for early detection of pre-emergency situations and their prevention;

— to develop optimal parameters for online non-stationary risk management and emergency prevention.

Management of synergistic risks is laid down at the design stage of pipeline systems. During their operation, high-quality diagnostics and recognition of pre-accident and emergency situations are required, as well as precise compliance with the requirements of the technological regime. Measures to prevent emergency situations are also mandatory [22, 23].

The unsteadiness of the above-mentioned risks (environmental impact, external and internal pressure, corrosion and aging of pipeline material) reduces the efficiency and safety of the process of pumping oil, gas and their processed products. The lack of reliable systems for monitoring and accounting for non-stationarity is a serious drawback of the existing technologies for predicting and determining the probability of an emergency and possible consequences, especially when it comes to:

— the operation of the object under the conditions of the maximum service life;

— branched heterogeneous pipeline systems with different operating modes [24, 25].

Thus, the main tasks for mathematical and technical modeling of non-stationary pipeline systems are related to forecasting:

— maximum permissible maximum and minimum pressure values generated by pumping units;

— maximum permissible time intervals for alarm activation and protective equipment activation;

— unsteadiness of hydraulic resistances in branched and unbranched pipeline systems;

— unsteadiness of external influences on the pipeline;

— rate of corrosion wear of metal from non-stationary external and internal impact on the pipeline walls.

It is also necessary to create maps of pumping modes, to determine the procedure for switching on and off pumping units, and to specify the requirements for existing organizations for monitoring, managing technological processes and equipment with mandatory monitoring of non-stationary risks [26, 27].

For these tasks it is necessary to examine the occurrence of corrosion due to the effects of time-dependent factors by the method of spectral correlation analysis, and perform calculations of:

— changes of stress-strain state of pipeline design,

— change of hydraulic resistance fluid,

— internal and external influence of wave patterns of non-stationary variables on the characteristics of the pipelines.

Conclusion. The main reason for pipeline accidents is their unsatisfactory technical condition. Transportation of hydrocarbons involves constant risks arising from corrosion of the pipeline body material, including salt deposits.

The experiment revealed that citric acid can be used as a co-inhibitor to prevent salt deposits and corrosion.

You can prevent accidents or avoid catastrophic consequences by using models of the origin and influence of non-stationary risks on transportation processes.

The compliance with all safety conditions will allow you to manage the operation of pipeline systems for oil and gas transportation in real time.

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Submitted 15.05.2020
Scheduled in the issue 13.07.2020

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UDC 656.137:504.06 https://doi.org/10.23947/2541-9129-2020-3-47-53

Container transportation in the urbanized environment using the «Internet of things» technology

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Introduction. The paper considers aspects of practical application of the “Internet of things” technology in the transport industry. The logistics problem of transporting empty containers is solved. The technology of container transportation in an urbanized environment is presented. The influence of the proposed technology on the environmental safety of transportation in the urban environment is considered.

Problem Statement. The purpose of this study is to solve the logistics problem of transporting empty containers using the “Internet of things” technology, and to estimate the technology influence on the environmental safety.

Theoretical Part. The technology is based on the smart container which is being developed. It can automatically fold and unfold and is controlled via a mobile app. It also allows you to remotely monitor the parameters of cargo transportation using built-in sensors. The reduction of harmful substances emissions while reducing the number of unproductive runs of transport as a result of the use of transformer containers is evaluated according to the criteria for reducing the mass consumption of harmful substances.

Conclusions. A new package product called "SmarBoxCity" is a unique and unparalleled product of the Fourth technical revolution. Its implementation makes it possible to improve the environmental safety of transport by reducing the emission of pollutants by 18.2 %.

Keywords: Internet of things, IoT, transportation, city, monitoring, container, environmental safety.

For citation: Korotkiy A. A., Nikolaev N. N. Container transportation in the urbanized environment using the «Internet of things» technology: Safety of Technogenic and Natural Systems. 2020;3: 47–53. https://doi.org/10.23947/2541-9129-2020-3-47-53

Introduction. In the modern world, in the context of the fourth technological revolution, there is fierce competition in all areas of production of goods and services. At the same time, modern technologies have risen to a completely unimaginable level, when they allow to implement complex projects for people, who are not narrow specialists in the field of information technology or robotics, but only have an idea, a clear (or not very clear) idea of who can buy it and why. In addition, you need some skills in mastering technical innovations and, if necessary, finding a team of specialists. And everything will work out, and not in many years, but very soon. The world is developing very quickly and will not wait. Let us look at one of the most important problems in the field of transport and the ways to solve it using the Internet of Things (IoT) technology.

Problem statement. A logistical problem associated with the transport of empty cargo containers as returnable containers. A huge volume of empty containers is transported by vehicles, which leads to unjustified expenses for fuel, labor, and depreciation of vehicles, causes traffic congestion, and has a huge impact on the environment.

In large cargo-handling points such as freight terminals, sea ports, companies are often able to avoid empty run of containers, provided a sufficiently effective operation of the logistics services. However, this task in an urbanized environment is quite difficult or not solved at all, since few urban infrastructure objects can simultaneously serve as cargo-generating and cargo-absorbing points, not to mention individuals who need to deliver their own cargo from point A to point B. When performing such transportation orders, reverse travel cannot be loaded. This significantly reduces the efficiency of container transport, despite their undeniable positive aspects.

Theoretical part. The idea of folding containers to improve transport efficiency is not new in itself. Such container systems are already operating in the world [1-6]. For example, a Staxxon container that folds vertically or a Cargoshell plastic container that folds horizontally [7]. There are also domestic developments [8]. Their advantages when transporting empty are obvious. However, they have one significant drawback in common: additional lifting and transport equipment (cranes or loaders) is required for their folding and unfolding. This reduces the efficiency and applicability of this technology.

But the modern world is a world of smart things that smart people learn to do without help.

There was an idea to teach a car folding container to fold and unfold without external equipment, as well as to communicate with the outside world in real time with information about its location, cargo condition, possible violations of transportation conditions, signals for opening or closing doors, and many other parameters. At the same time, with the help of special equipment (soft containers), the smart container will be able to transport not only package cargo, but also bulk or liquid cargo, which will significantly expand its scope of use.

Of course, such a smart thing can't exist on its own. Its successful application requires support for mobile and web applications, servers, and cloud technologies, as well as an algorithm for using a smart container in this system using road transport, and an algorithm for working with road transport, taking into account the interaction of all participants in the process and the discretely changing states of these elements of the system (Fig. 1) [9]. As a rolling stock, it is rational to use self-loaders with cranes of the appropriate load capacity.

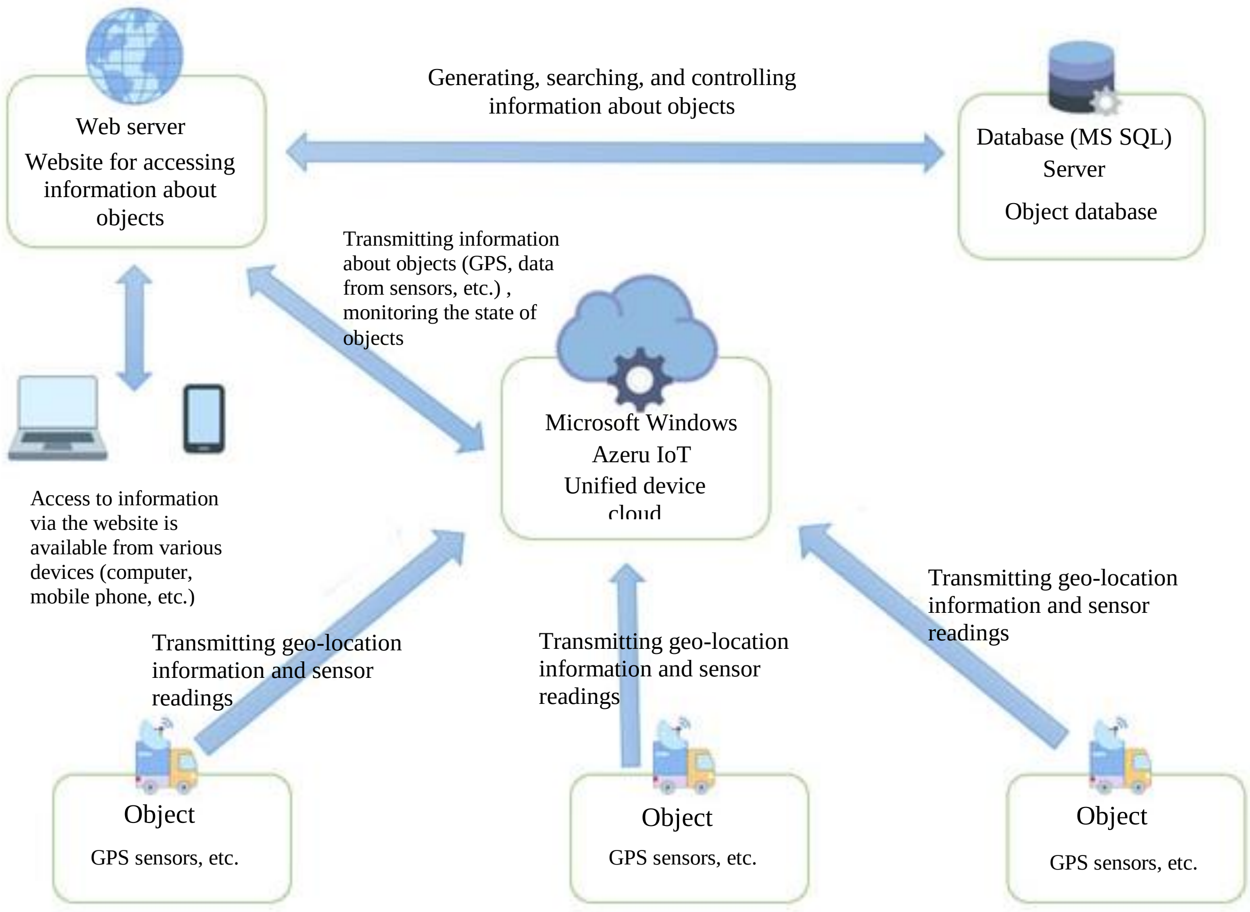
Web server
Website for accessing information about objects
Generating, searching, and controlling information about objects
Database (MS SQL) Server
Object database
Transmitting information about objects (GPS, data from sensors, etc.) , monitoring the state of objects
Microsoft Windows Azeru IoT Unified device cloud
Access to information via the website is available from various devices (computer, mobile phone, etc.)
Transmitting geo-location information and sensor readings
Transmitting geo-location information and sensor readings
Transmitting geo-location information and sensor readings
Object
GPS sensors, etc.
Object
GPS sensors, etc.
Object
GPS sensors, etc.

Fig. 1. Operation diagram of the smart container system

Now let us look at what we need to implement such an idea. First, the container structure itself is one of the previously developed or newly created ones [8]. Second, it is the system of driving mechanisms for folding and unfolding the container. This can be electric motors or such an interesting implementation of reciprocating motion as an electric linear actuator. These are the most expensive parts of the smart container.

And, what will serve as the "brains" of this smart thing is the most interesting. There are a lot of options now: from Arduino microcontrollers (Uno, Mega, Nano) and ESP boards equipped with Wi-fi and Bluetooth (8266 and ESP 32) with a price of several hundred rubles, to advanced Raspberry Pi from Microsoft and some similar developments with a cost of several thousand rubles. These microcontrollers are made to "think" by a special firmware (called "sketch") written to the permanent memory of the microcontroller in one of the languages supported by the board. There is a technology for creating such programs without using language code based on the use of ready-made blocks in a graphical environment (Flprog, XOG, etc.).

You will also need a wide variety of sensors (load cell, temperature, humidity, position, shock, tightness, etc.) and auxiliary elements (voltage stabilizers and dividers, relays, motor drivers, and so on).

As a result, after developing and connecting all the hardware and software parts of the system together, we get a package product consisting of the smart containers themselves (Fig. 2), mobile applications for car drivers and users (transportation customers) with the container management function, and an Internet site with the functionality of calculating the cost of transportation, processing and paying for a transportation request.

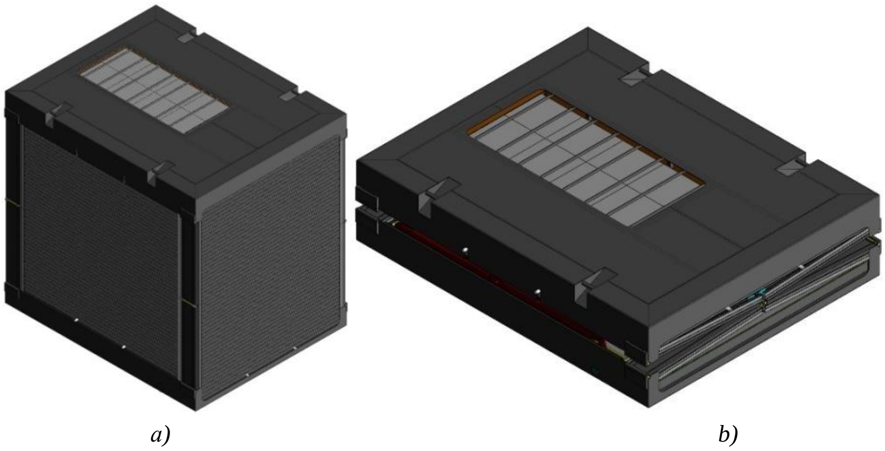
a) b)

Fig. 2. General view of the smart container in the working (unfolded) (a) and transport (assembled) (b) position

The proposed system is called SmarBoxCity [10], and the first copies market launch is in 2020.

Next, you need to evaluate how to reduce the negative impact of transport on the city's environment when implementing the SmarBoxCity package product.

To assess the reduction of the negative impact of road transport on the environment when implementing the SmarBoxCity package product, we will perform a comparative calculation of the amount of pollutants emitted when performing the same volume of transport using conventional containers and the proposed transformer containers.

As a vehicle for comparative analysis, we will choose a KAMAZ 65117 with a Ferrari 726 articulating crane.

Let us assume that you need to transport a single-piece cargo that occupies four medium-tonnage containers at a distance of 10 km between the shipper and the consignee. The initial data for the calculation are shown in Table 1.

Table 1

Source data for calculating the environmental performance of SmarBoxCity

Transport system parameters	Options	
	Regular containers	SmarBoxCity
Car model	KAMAZ 65117 with Ferrari 726 articulating crane	
Number of containers, pcs.	4	4
Number of cars, pcs.	2	2
Transportation distance, km	10	10
Zero haul, km	5	5

The amount of pollutants released per unit of engine power is determined by the dependencies shown in Table 2 [11].

Table 2

Dependencies for calculating the emission of pollutants from a diesel engine

Pollutant	Range of relative power changes $\overline{N}$	Concentration, c_i, g/m^3
CO	0–1,0	$5{,}6754\overline{N}^4 - 11{,}758\overline{N}^3 + 9{,}9078\overline{N}^2 - 3{,}5046\overline{N} + 0{,}7996$
NO$_x$	0–1,0	$4{,}2667\overline{N}^4 - 19{,}2\overline{N}^3 + 18{,}933\overline{N}^2 - 1{,}2\overline{N} + 0{,}7$
C	0–1,0	$-1{,}332\overline{N}^4 + 2{,}7531\overline{N}^3 - 1{,}5837\overline{N}^2 + 0{,}3629\overline{N} + 0{,}0194$
$C_{20}H_{12}$	0–1,0	$2{,}4308\overline{N}^2 - 0{,}8536\overline{N} + 0{,}4121$, mkg/m^3

Average speed of transportation in an urban environment [11]

$$\text{v}_{jг} = 0{,}4467 \cdot 1{,}8665\text{v}, \qquad (1)$$

where v – the average speed of traffic flow, m/s.

$$\text{v}_{jг} = 0{,}4467 \cdot 1{,}8665 \cdot 4{,}24 = 3{,}53 \text{ m/s.}$$

Mass flow rate M_i, *i*-th pollutant [11]

$$M_i = Q_{Oг} c_i, \qquad (2)$$

where $Q_{Oг}$ – where is the volume flow of exhaust gases, m^3/s;

c_i – concentration of i-th pollutant in exhaust gases, g/m^3.

Exhaust gas volume flow rate [11]

$$Q_{Oг} = 0{,}0007\text{v}^2 - 0{,}0256\text{v} + 0{,}3184, \qquad (3)$$

$$Q_{Oг} = 0{,}0007 \cdot 3{,}53^2 - 0{,}0256 \cdot 3{,}53 + 0{,}3184 = 0{,}237 \text{ (m}^3\text{/s).}$$

The relative power of the engine is determined from the equation [11]

$$\overline{N}N_{ном} = \frac{\left[k_{ф}\rho_{в}F_s v_j^{\,2} + mg\cos\gamma\left(f \pm tg\gamma\right) \pm \delta_{вр}am\right]v_j}{\eta_{тр}}, \qquad (4)$$

where $\overline{N}N_{ном}$ – the effective power of the engine ($N_{ном}$ –номинальная rated power of the engine, W), W;

$k_{ф}$ – flow coefficient;

$\rho_{в}$ – air density,, $\rho_{в}$ = 1,293 kg/m^3;

F_s – the area of the front surface of the truck, m^2 (we take up F_s =7,5 m^2);

m – weight of the loaded truck, kg (we take up *m* = 25900 kg);

g – acceleration of gravity, m/s^2;

f– coefficient of rolling resistance, we take up *f* = 0,02;

$\delta_{вр}$ – rotational inertia coefficient;

a – vehicle acceleration, m/s;

$\eta_{тр}$ – mechanical efficiency of the transmission.

The expression $\delta_{вр}a$ is determined as [11]

$$\pm\delta_{вр}a = g\left(0{,}5502v^{-1{,}11} - \Psi\right), \qquad (5)$$

where Ψ – the coefficient of reduced road resistance, $\Psi = 0{,}02$.

$$\delta_{вр}a = 9{,}87\left(0{,}5502 \cdot 3{,}53^{-1{,}11} - \Psi\right) = 1{,}142.$$

The mechanical efficiency of the transmission is determined as [11]

$$\eta_{mp} = -1,3238\bar{N}^3 + 1,118\bar{N}^2 - 0,031\bar{N} + 0,8755 . \tag{6}$$

So, from equation (4) we get

$$\bar{N} = \frac{\left[0,45 \cdot 1,293 \cdot 7,5 \cdot 3,53^2 + 25900 \cdot 9,87 \cdot 1 \cdot 0,02 + 1,142 \cdot 25900\right] \cdot 3,53}{154000(-1,3238\bar{N}^3 + 1,118\bar{N}^2 - 0,031\bar{N} + 0,8755)} . \tag{7}$$

We get four roots, of which the real one is $\bar{N} = 0,351$.

Then for KAMAZ 65117

$c_{NO_x} = 4,2667 \cdot 0,351^4 - 19,2 \cdot 0,351^3 + 18,933 \cdot 0,351^2 - 1,2 \cdot 0,351 + 0,7$,

$c_{NO_x} = 1,846$ $г/м^3$;

$c_{CO} = 5,6754 \cdot 0,351^4 - 11,758 \cdot 0,351^3 + 9,9078 \cdot 0,351^2 - 3,5046 \cdot 0,351 + 0,7996$,

$c_{CO} = 0,368$ $г/м^3$;

$c_C = -1,332 \cdot 0,351^4 + 2,7531 \cdot 0,351^3 - 1,5837 \cdot 0,351^2 + 0,3629 \cdot 0,351 + 0,0194$,

$c_C = 0,051$ $г/м^3$;

$c_{C_{20}H_{12}} = 2,4308 \cdot 0,351^2 - 0,8536 \cdot 0,351 + 0,4121$,

$c_{C_{20}H_{12}} = 0,412$ $мкг/м^3$.

Thus, the mass consumption of pollutants by a single vehicle

$M_{NO_x} = 0,237 \cdot 1,846 = 0,4375$ g/s;

$M_{CO} = 0,237 \cdot 0,368 = 0,0872$ $г/с$

$M_C = 0,237 \cdot 0,051 = 0,0121$ $г/с$;

$M_{C_{20}H_{12}} = 0,237 \cdot 0,412 = 0,0976$ mkg/s.

The mass consumption of pollutants by vehicles involved in the process is determined as [11]

$$\sum M_{ijk} = M_{ijk} \cdot m \cdot L / \upsilon , \tag{8}$$

where *m* – the number of vehicles involved in the process, pcs.;

L – total distance for transportation, km.

We will calculate the vehicle mileage for the compared options and determine the mass emission of pollutants during delivery.

According to the traditional container scheme, one empty container is loaded for each vehicle at the container base. Since there are two cars for four containers, they will have to make two zero cycles (from the storage location to the shipper). After loading the containers, you will need to perform one ride with each loaded container out of four.

According to the scheme with the use of transformer containers, one car can carry up to four stacked containers, that is, as many as the shipper needs. Thus, they can be delivered to the loading point on a single ride. Loaded transformer containers are transported one at a time by car, as well as the traditional ones.

Let us fill in Table 3 according to the above reasoning.

Table 3

Calculation results of the environmental efficiency of SmarBoxCity

Parameters	Options	
	Regular containers	*SmarBoxCity*
Total mileage for completing the transportation task, km	55	45
Mass flow:		
NO_x, g	13633,14	11154,39
CO, g	2717,28	2223,23
C, g	377,05	308,50

Parameters	Options	
	Regular containers	*SmarBoxCity*
$C_{20}H_{12}$, mkg	3041,36	2488,39

Table 3 shows that the use of the SmarBoxCity package product reduces the emission of harmful substances to the environment by 18.2%.

Conclusion. A new package product on the market of transport and logistics services in an urban environment called SmarBoxCity is a unique product of the fourth technological revolution. Its implementation makes it possible to improve the environmental safety of transportation by reducing the emission of pollutants by 18.2%. Of course, we expect significant technological and economic efficiency of this package product. Their comprehensive assessment is the task of further research.

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Submitted 15.05.2020

Scheduled in the issue 07.07.2020

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UDC 331.43+504.05 https://doi.org/10.23947/2541-9129-2020-3-54-60

Improving the environmental and industrial safety of the locomotive depot

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Introduction. The article is devoted to improving the process of waste disposal in a locomotive depot as a factor for increasing its environmental and industrial safety. In particular, the issue of regeneration of wiping material contaminated with motor oils is considered. Oil waste occurs when replacing waste oils in diesel locomotives.
Problem Statement. There are four reasons for changing the oil: dilution, increased viscosity and water content, and contamination by mechanical particles. Oil is replaced by draining, the rest, which cannot be cleaned by this method, is removed manually with a rag. The oil obtained by draining is placed in a tank for subsequent combustion in a boiler depot, and the oil collected with rags is stored in separate containers for subsequent transportation to an industrial landfill. Such oiled rags have the potential for processing, the task of implementing the method of which is solved in this study.
Theoretical Part. The paper reveals the design features of a patentable device for pressing-out oiled rags, the introduction of which will provide the opportunity to increase the allocated waste oil in the form of a liquid suitable for burning in a furnace, and the possibility of recycling rags.
Conclusion. The main environmental effect of the introduction of a device for processing oiled rags is the reduction of the flow of waste oil into the environment. The decrease in the annual amount of waste oil entering the environment will be about 26.5 t/year. In addition, the use of the device will improve the safety of workers when disposing of rags due to its processing in a closed container and will reduce the content of harmful oil vapors in the air of the working area.

Keywords: oil processing, locomotive depot, environmental effect, rag pressing device, engineering.

For citation: Tyurin A. P. Improving the environmental and industrial safety of the locomotive depot: Safety of Technogenic and Natural Systems. 2020;3: 54–60. https://doi.org/10.23947/2541-9129-2020-3-54-60

Introduction. The analysis of the distribution of waste received during the operation of railway transport shows that the main sources of pollution of natural systems are railway stations [1-3]. At a railway station, one of the key sources of waste is locomotive depots, which generate waste materials that have been replaced during ongoing, preventive and major repairs. Waste generated during repairs is dangerous, first of all, for employees of depots where repairs are carried out. They are a threat from the point of view of industrial and environmental safety. It was found that the negative impact of pollution on the environment spreads not only in the immediate vicinity of the roadside, but also within a radius of several kilometers from the railway tracks [4]. Therefore, the timely and most complete disposal of the resulting waste is one of the main factors of labor safety.

In this regard, there is a need for a wider use of scientific and technical achievements at railway transport enterprises by introducing waste-free and low-waste technological schemes for pollutants processing in addition to the existing innovations [5]. The article is devoted to improving the process of waste disposal in a locomotive depot as a factor affecting environmental and industrial safety.

Problem statement. Railway locomotive depots use six- and eight-axle locomotives with a capacity of 750 to 2000 kW for shunting. The arrangement of locomotive depots serves to fulfill the tasks facing it. This means the following buildings and structures on its territory: a fuel warehouse (for storing diesel fuel, oils and lubricants); a turning circle or a turning triangle (for carrying out periodic or technological turns of the locomotive); a locomotive equipment point; a locomotive maintenance point; a locomotive repair shop; stations of rheostat tests (for carrying out rheostat tests of locomotives and diesel trains); auxiliary shops (for performing repairs of individual units and locomotive units), administrative and household buildings and structures.

Railway transport enterprises generate up to 5 million tons of industrial waste annually, of which up to 70% is not disposed of [6]. The production processes of the industry are characterized by a wide variety of these processes, which leads to a wide classification of industrial waste, shown in Fig. 1.

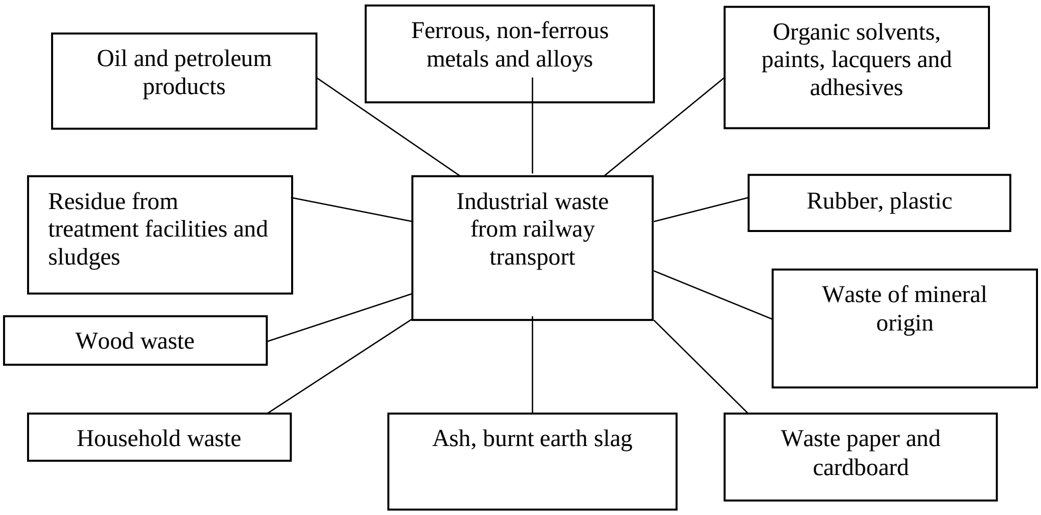
Oil and petroleum products
Ferrous, non-ferrous metals and alloys
Organic solvents, paints, lacquers and adhesives
Residue from treatment facilities and sludges
Industrial waste from railway transport
Rubber, plastic
Wood waste
Waste of mineral origin
Household waste
Ash, burnt earth slag
Waste paper and cardboard

Fig. 1. Types of rail transport waste

Despite the variety of types of waste indicated in Fig. 1, in the context of this article, waste of mineral origin in the form of spent mineral motor oils is of interest [7-9].

The main activity of the depot is the maintenance of railway transport, which means current, preventive and major repairs. The number and type of diesel locomotives under repair are diverse, with about 550 vehicles serviced per year. The depot is usually located on a site about 800×900 m in size. The number of employees is about 250 people. Fig. 2 is the depot diagram showing the source and types of waste generated.

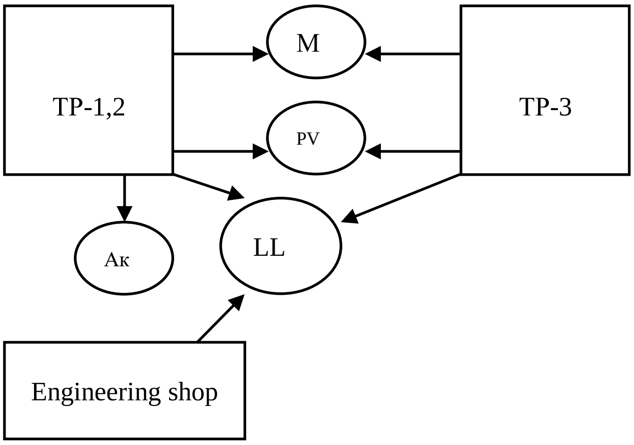

Fig. 2. Locomotive depot diagram:
TR-1,2 — shop of capital and preventive repairs; TR-3 — shop of current repairs
(Aк — used batteries; LL — used fluorescent lamps; M — used oil; PV — oiled rags)

All waste received during the operation of the locomotive depot is divided into two types:

1. Waste disposed of at the enterprise itself.

2. Waste disposed of outside the enterprise. This waste is disposed of in various designated locations, and the locomotive depot is only responsible for collection and storage before removal.

The waste disposed of outside the enterprise mainly includes fluorescent lamps, used batteries, oiled rags. The consumption of lamps is about 2500 pcs/year. Lamps are sorted by type and stored in their original packaging (cardboard boxes) in undamaged condition. The transfer of lamps for demercurization is made under an agreement with a third-party company. Used batteries and used electrolyte in the containers in which they are stored, are loaded one by one and transported by rail for processing at special enterprises. The source of waste oil in the form of oiled rags is exported to a special landfill for industrial waste.

Table 1 shows that the amount of used motor oils, and waste in them is significant. It can be seen that the cleaning material contaminated with oils is not completely neutralized and therefore is a source of potential contamination.

Table 1

Amount of used motor oil at the enterprise

Name of the types of waste oils	Waste generation, t, average per year	Use of waste, t	Waste neutralization	Amount of waste for potential disposal, t
Used mineral oils of various categories in liquid form	279,719	279,712	–	0,000
Cleaning material contaminated with oils (oil content of 15 % or more)	33,67	–	12,27	21,40
Cleaning material contaminated with oils (oil content no more than 15 %)	0,151	–	–	0,151

Waste lubricating oils is generated in the process of diesel locomotives waste oils replacement. There are four reasons for oil change: dilution, increased viscosity and water content, and contamination with mechanical particles (sand, dirt). The oil is changed by draining, and the residue is removed manually with a rag. On average, it is necessary to drain up to 50,000 kg of oil per year due to its liquefaction. The oil obtained by draining is placed in a container for subsequent combustion in the depot boiler room. Oil collected by rags is stored in separate containers, which are taken to the landfill for burial. Such oiled rags need to be recycled. The task is to develop an acceptable method for its environmentally safe disposal.

Development of a device for oiled rags pressing

A patentable device for oiled rags pressing is intended to be used in the shop of routine repairs — TR-3 (Fig. 2). Fig.3 shows the scheme of such a device.

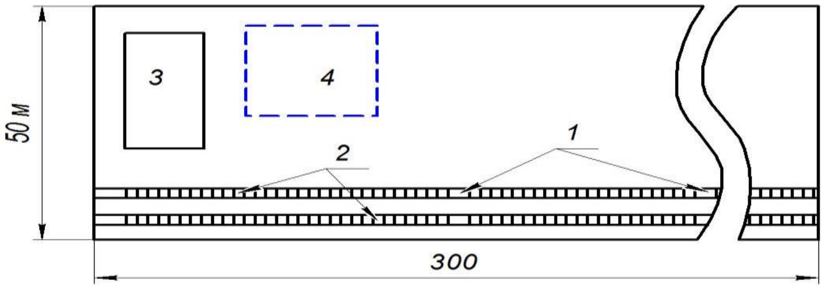

Fig. 3. Structure diagram of the device for oiled rags pressing:
1 — service passageways; 2 — inspection pits; 3 — washing machine;
4 — location of the unit

The workshop is a rectangular building of 300×50×4 m. The main place of work is the observation pits laid under the tracks, and the washing machine. At the inspection pits, the necessary inspection of the wheel pairs is performed, the waste oil is drained, and the rest of the oil is collected by rags.

The goals of developing a device based on the technical solution described in the patent [10] are:

— the possibility to increase the allocated waste oil in the form of liquid suitable for combustion in the boiler depot;

— the possibility of reusing the rags used to collect oil.

The principle on which the operation of this device is based: oiled waste rags containing up to 1.5 kg of oil per 1 kg of rags are placed in the container where the piston is located. Next, the piston squeezes the rag with a screw drive, resulting in the oil being squeezed out, and a semi-dry rag suitable for further use remains in the container. Laying oiled rags and cleaning semi-dry rags is done manually, and the movement of the piston is by means of a screw drive and an electric motor. The pressed oil is removed to a separate container for further processing.

The structure of the device for pressing oiled rags is shown in Fig. 4. Table 2 shows an approximate list of the main components of the unit and their dimensions.

Table 2

Main components of the device and their dimensions

No.	Major component	Number, pcsт	Dimensions, mm			Wall thickness, mm
			Length	Width (diameter)	Height	
1	Electromotor (4А132S6У3)	1				
2	Gearbox (1Ц3у-355-50-22м)	1	150	250	400	
3	Tube (pipe GOST 8732-78)	1	800	402		16
4	Coupling rod	1	24	380		
5	Screw	1	1600	40		
6	Protective cover of the screw (pipe GOST 8734-75)	1	800	48		1.0
7	Stop (I-beam)	1	790			–
8	Oil collection tank	1	400	400	400	2
9	Bricks	146	250	120	65	–

Electric motor 1 through gearbox 2 rotates screw 3, which rests on the support 13. Due to the movement of the screw, the piston, rod 5 inside container 4 begin to move. During the movement, the volume occupied by the cloth decreases continuously, and the oil begins to squeeze from rags, which through valve 7 begins to flow from tank 4 into tank 8. After the rags would give most of the oil, valve 7 closes and motor 1 starts to move in the opposite direction. After the rod reaches the stop, the electric motor is stopped, and then the semi-dry rag is manually removed from container 4.

When a sufficient amount of oil is collected in container 8, it is poured into container 11 with the help of tap 10 for further processing. Gauge glass 10 is used to determine the presence and quantity of water in the oil mixture. If there is water, it is lowered, controlling the flow through gauge glass 10 until it completely escapes.

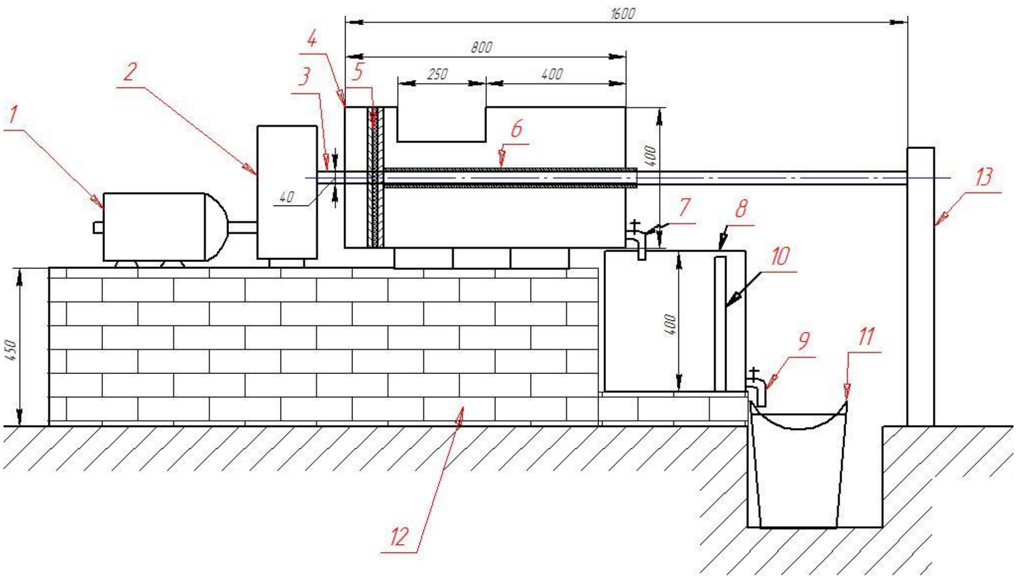

Fig. 4. General view of the installation:
1 — electric motor; 2 — gearbox; 3 — screw; 4 — container; 5 — rod; 6 — pipe connected to the rod; 7 — oil tap from the container 4; 8 — oil tank; 9 — oil tap from container 8; 10 — gauge glass; 11 — bucket;
12 — foundation; 13 — screw stop

The mode of operation of the device is determined by the amount of oiled rags during the shift. This amount is on average 35-40 kg, increasing up to 60 kg during major repairs. Therefore, the device must process this amount of oiled rags in 1 shift. Given the intermittent and uneven flow of oiled rags, which is caused by different rates of oil collection in different parts of the shop and during repairs of different models of locomotives, it is assumed to load the oiled rags as they arrive in one container.

Based on the presence of a daily receipt of rags in the amount of 35–40 kg and, taking into account their physical properties, it is necessary to have a container 2-2,5 times bigger than the volume occupied by the rags. 100 liters can be considered as the optimal volume.

For container 4, the most convenient form is cylindrical. Then the container volume is calculated as:

$$V = \pi \cdot R^2 \cdot H\,, \tag{1}$$

where V is the volume of the container, l; R is the radius of the container 4; H is the total length of the container 4 (H = 0.8 m).

The main parameter used for calculating the operation of this unit is the speed of oil flow from container 4 to container 8 through tap 7. Taking into account the oil viscosity to avoid splashing, the oil flow rate is no more than 20 l/min. It follows that the volume of oil displaced is equal to

$$V = \pi \cdot R^2 \cdot h\,, \tag{2}$$

where V is the volume of oil being displaced, R is the radius of the cylinder, and h is the length that the rod travels within a minute.

From formula 2, we get the value of h equal to 0.08 m.

When using a screw mover to move the rod, its speed can be calculated using the formula:

$$h = \omega \cdot t\,, \tag{3}$$

where ω is the number of revolutions of the screw in 1 minute, t is the pitch of the screw.

In this case, the calculation is based on the value of ω, which gives electric motor 1 through gearbox 2. The available gearbox has a value of ω equal to 18 rpm. It follows that the pitch of the screw should be 0.45 sm or 4.5 mm. Gear ratio Z = 55.5.

From the available electric motors, a 5.5 kW 4a132s6u3 electric motor with a rotation speed of 1000 rpm was selected. The rationale for choosing an electric motor is the number of revolutions provided together with the gearbox.

The calculation of oil collection container 8 is based on the fact that it should contain all the oil that flows from container 4. Based on the volume of daily receipt of oiled rags, and taking into account the oil content in it, up to 20-25 liters of oil is formed per shift. Given the same criteria as for container 4, it is necessary to have a volume of 2-2.5 times bigger than the volume of oil. For the ease of manufacturing, a cube with dimensions of 40×40×40 sm is accepted.

The main environmental effect of the introduction of the device for processing oiled rags is the reduction of the flow of petroleum products (waste oil) to the environment. This is due to the fact that the main amount of oil will be released in its pure form and disposed of by burning in the boiler room at the depot premises. The reduction in the annual amount of waste oil entering the environment will be about 26.5 t/year. The economic effect of implementing the device is determined by the speed of its payback. At the same time, it is necessary to take into account the cost of manufacturing the device, its operation, as well as reducing the cost of removing waste oil/rags.

Conclusion. The issues of improving the industrial and environmental safety of locomotive depots can be solved consistently based on the analysis of pollution sources. Locomotive depots are a source of waste of various hazard classes, starting from the first and ending with the last: scrap of ferrous and non-ferrous metals, fluorescent lamps, batteries, etc. Some of the waste is disposed of outside the enterprise and therefore does not pose any danger to the natural environment. So, in relation to this study, the disposal of used rags occurs outside the depot by burial at a special landfill. Waste oil is disposed of by burning in the depot boiler room, except for the oil collected by rags. At the same time, this rag contains a large amount of oil — up to 1.5 kg per 1 kg of dry rags. In this regard, for more rational use of oiled rags, a special patentable device for extracting oil from used rags for the purpose of its reuse, at least twice, has been proposed and constructively developed. The environmental effect of using the device will be achieved by reducing the amount of oiled rags disposed of (from 50 to 10.5 t/year) and by reducing its oil content (from 1.5 to 0.5 kg of oil per 1 kg of rags). This will reduce the flow of oil to the environment from 30 to 3.5 t/year.

In addition, the use of the device will improve the safety of workers when disposing of oiled rags due to its processing in a closed container and will help reduce the content of harmful oil vapors in the air of the work area.

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Submitted 18.05.2020
Scheduled in the issue 06.07.2020

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UDC 331.45 https://doi.org/10.23947/2541-9129-2020-3-61-66

Separate waste collection system introduction in Russian educational institutions (by the example of Letovo School)

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Introduction. Environmental pollution by solid household waste is a serious ecological problem, as it causes degradation of natural ecosystems and alienation of territories. There is about 40,000 km^2 occupied by landfills in Russia, and this area is constantly increasing, as every year Russia throws out more than 300 kg of waste.

Problem Statement. To solve this problem, it is necessary to develop a system of separate waste collection, as well as the formation of an ecological outlook among young people and students and a thrifty attitude to the natural environment. A specific example of this approach is described in this article.

Theoretical Part. Main stages of organization of separate waste collection in school Letovo School, implemented by students, are considered as an example.

Conclusions. 5.6 tons of waste was collected and recycled during the year of operation. The project has received approval in the school environment and can be implemented with minimal costs in almost all Russian educational organizations.

Keywords: waste, separate waste collection, recycling, rational consumption, resources, sustainable development, environment.

For citation: Pleshko M. V., Pleshko E. M. Separate waste collection system introduction in Russian educational institutions (by the example of Letovo School): Safety of Technogenic and Natural Systems. 2020;3: 61–66. https://doi.org/10.23947/2541-9129-2020-3-61-66

Introduction. The problem of efficient disposal of municipal solid waste (hereinafter referred to as waste) for Russia as a whole and the city of Moscow, as its capital and the largest agglomeration in particular, remains very serious today. In Russia, about 40,000 km^2 of territories are occupied by landfills, and this area is constantly increasing, as every Russian throws out more than 300 kg of waste every year [1]. In a number of cities in the Moscow region (Klin, Kolomna, Troitsk, Balashikha, etc.), an active protest movement of local residents against the landfills and dumps has been launched. The environmental situation in the surrounding areas is constantly deteriorating, and there are cases of mass poisoning of children and adults.

Incineration of waste, despite the constant improvement of the technologies used, does not completely solve environmental problems. This is, in particular, due to an increase in the share of the polymer component in the waste, the combustion of which leads to the formation of supertoxic substances. This approach is also not justified from an economic point of view [2].

The most promising areas include the organization of separate collection and recycling of waste. In particular, one of the tasks of the national project "Ecology" is to bring the level of municipal waste sent for recycling up to 60% in 2024 [3]. According to the adopted amendments to article 114 of the Basic law, the government of the Russian Federation is obliged to implement measures aimed at creating favorable living conditions for the population, reducing the negative impact of economic and other activities on the environment, creating conditions for the development of the system of environmental education of citizens, and fostering environmental culture [4]. Separate waste collection is also linked to the sustainable development goals adopted by the UN General Assembly back in 2000 [5]. The introduction of modern waste processing technologies also has a strong economic potential, both in the material and energy sectors [6].

Separate waste collection — selective collection of waste for further processing in order to avoid environmental pollution [7]. Throughout the world, it is mostly voluntary, but its promotion can also be based on targeted economic incentives, as evidenced by the positive experience of South Korea and a number of European Union countries [8].

In many cities and regions of Russia, steps are being taken to organize separate waste collection such as plastic bottles, metal cans, glass containers, waste paper and cardboard. These wastes can be easily processed using modern production technologies. Ballpoint pens, markers, toothbrushes, and other polymer products of mass consumption are also effectively processed [9].

It is much more difficult to recycle Tetra Pak packaging (for juices, dairy products, etc.), oversized and small plastic bags. Tetra Pak packaging is difficult to recycle, as it consists of several layers, which must first be separated from each other and thoroughly cleaned. Oversized plastic and bags are difficult to sort, but the latter can be crushed and added, for example, to road blocks to improve their performance.

The problem is also complicated by the lack of scientifically based classification of household waste, the need to use complex technological equipment and economic justification for each specific type of waste [10].

Certain mass categories of household waste in Russia today are practically impossible to recycle. These are foil wrappers and packages, paper cups, tea bags, diapers, etc. To reduce the volume of such waste, it is necessary to change the culture of consumption, to form an ecological worldview and a thrifty attitude to the natural environment among the population and, above all, among young people and students. A specific example of this approach is described in this publication.

Problem statement. In September 2018, Letovo School for gifted children was opened in Moscow. Its distinctive feature is training of students on individual educational trajectories in the format of day, week or full board education. Most of the time during the year, students spend time at school, where they develop not only educational, but also personal competencies.

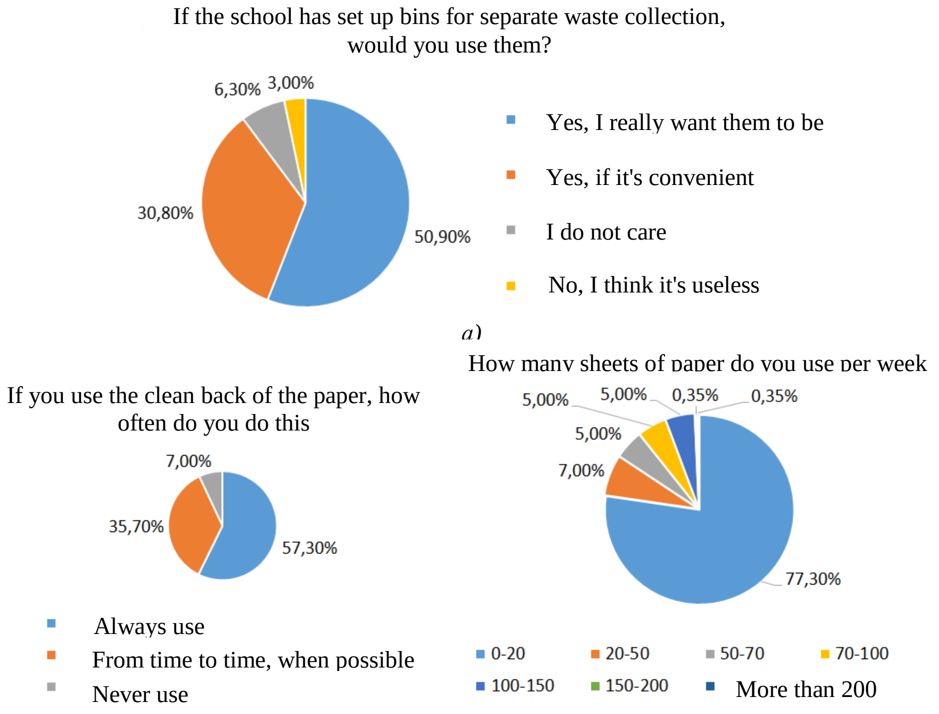
Separate collection of waste in the facility was initially planned, but for a number of reasons it was postponed indefinitely. The initiative group, consisting entirely of school students, drew attention to this problem, and then developed and implemented a project for organizing a separate collection system in the institution, aimed at solving the following main tasks:

1. Examination of readiness of students and school staff to separate waste collection by sociological methods.
2. Interaction with the school administration and the recycling company on the gradual introduction of a system of separate collection and disposal of waste.
3. Development of schemes and places for bins for separate waste collection on school grounds.
4. Promotion of the importance of separate waste collection through various tools.

A description of the solution to these problems is presented in the theoretical part of the publication.

Theoretical part. Stage one. Sociological research. The stage was implemented between October and November 2018. The purpose of the examination is to assess the readiness of the school community to accept the idea of separate waste collection. The survey was conducted among the students and employees of the institution. A total of 171 people took part in the survey, which was about 60% of all students and employees at that time. The survey was conducted remotely using a form developed by Google. This made it possible to reduce the duration of the survey and eliminate unnecessary paper consumption. The questionnaire included three simple questions that help achieve the stated goal of examination and focus the attention of the school community on one of the most pressing problems of lean consumption (the use of paper for educational purposes).

The results of statistical processing of examination data of representatives of the school community are shown in Fig. 1.



a)

b)

c)

Fig. 1. The results of examination of the school community representatives

It was found that 50.9% of respondents wanted the trash bins to be installed, another 39.8% would use them if it was convenient, 6% said they did not care, and only 3% were against it (Fig. 1A).

77.8% of respondents used less than 20 sheets of paper per week, 7% — from 20 to 50 sheets, 5% of respondents used 50-70, 70-100 and 100-150 sheets, respectively, and less than 1% of respondents used over 150 sheets per week (Fig. 1b).

57.3% of respondents used the back side of a used piece of paper from time to time, 35.7% used it constantly, and 7% never used it (Fig. 1c).

The obtained results allowed us to draw a conclusion about the timeliness of the project implementation and the readiness of the school community for it. In addition, an important problem of lean consumption was revealed, which was very relevant from the point of view of the organization of the educational process and required a comprehensive approach to its solution.

Stage two. Organizational. The introduction of separate waste collection is possible only with the consent of the administration of the educational institution. After the presentation of the project concept and the results of the sociological research to the school management, the project was approved and received broad support. The institution has signed a contract with the processing company "EcoTechnologies" for separate waste collection. The company provided the school with 27 separate collection sets with three sections, free of charge:

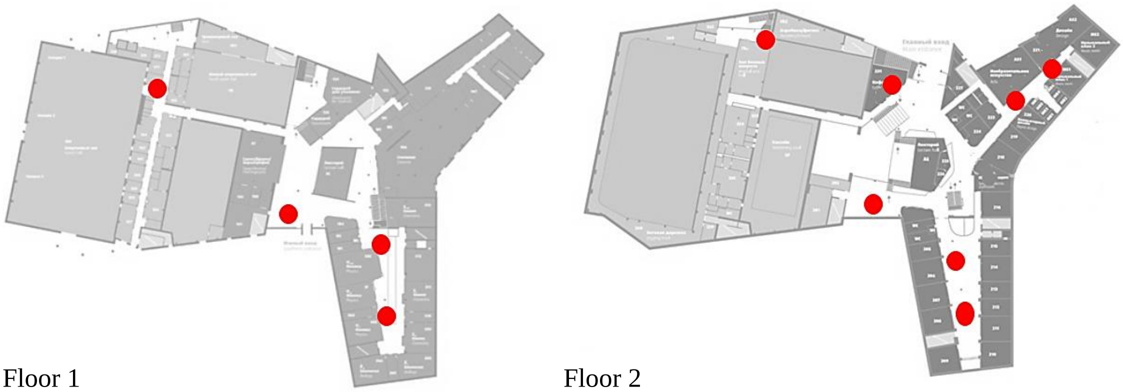
1) for paper and cardboard;

2) for plastic waste, glass bottles and metal cans;

3) for other waste.

Additionally, there are 15 bins for collecting paper, two containers for collecting plastic lids, three boxes for collecting sheets of paper used on one side, and two containers for batteries recycling.

Stage three. Integration. The school administration gave the initiative group the opportunity to choose themselves the places to install separate garbage collection sets. Based on the logistics analysis using brainstorming elements, key locations were identified in the main building of the school, as well as in boarding houses, where the most intensive flows of movement of people, as well as sources of waste generation were identified (Fig. 2).



Floor 1

Floor 2

Fig. 2. Schemes for placing bins for separate waste collection in the main building of the school

The project was officially launched on March 1, 2019. On the same day, a meeting was held with the Director of the company "EcoTechnologies" Konstantin Rzaev, where he told students and employees about the current issues of organizing separate collection and recycling of waste.

Stage four. Popularization of the project. The stage was implemented in the following main areas:

1. Promotion of the project at various school events.
2. Promotion in the mass media of an educational institution.
2. Visual campaigning and individual work.

The following are specific examples of project promotion in the areas listed above.

On March 1, 2019, the project team presented the project at the school-wide assembly and prepared an article for the school newspaper.

In March–April 2019, design solutions were developed, visual agitation tools were produced and placed on the school grounds to promote the project (Fig. 3).

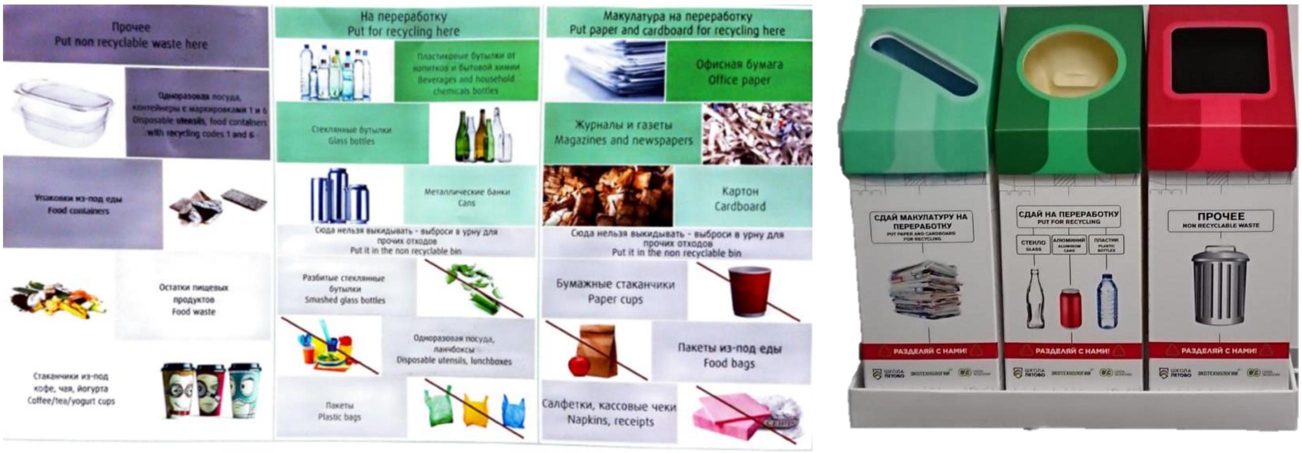

Прочее
Put non recyclable waste here
Одноразовая посуда, контейнеры с маркировками 1 и 6
Disposable utensils, food containers with recycling codes 1 and 6
Упаковки из-под еды
Food containers
Остатки пищевых продуктов
Food waste
Стаканчики из-под кофе, чая, йогурта
Coffee/tea/yogurt cups
На переработку
Put for recycling here
Пластиковые бутылки от напитков и бытовой химии
Beverages and household chemicals bottles
Стеклянные бутылки
Glass bottles
Металлические банки
Cans
Сюда нельзя выкидывать - выброси в урну для прочих отходов
Put it in the non recyclable bin
Разбитые стеклянные бутылки
Smashed glass bottles
Одноразовая посуда, ланчбоксы
Disposable utensils, lunchboxes
Пакеты
Plastic bags
Макулатура на переработку
Put paper and cardboard for recycling here
Офисная бумага
Office paper
Журналы и газеты
Magazines and newspapers
Картон
Cardboard
Сюда нельзя выкидывать - выброси в урну для прочих отходов
Put it in the non recyclable bin
Бумажные стаканчики
Paper cups
Пакеты из-под еды
Food bags
Салфетки, кассовые чеки
Napkins, receipts
СДАЙ МАКУЛАТУРУ НА ПЕРЕРАБОТКУ
PUT PAPER AND CARDBOARD FOR RECYCLING
СДАЙ НА ПЕРЕРАБОТКУ
PUT FOR RECYCLING
СТЕКЛО
GLASS
АЛЮМИНИЙ
ALUMINUM CANS
ПЛАСТИК
PLASTIC BOTTLES
ПРОЧЕЕ
NON RECYCLABLE WASTE
РАЗДЕЛЯЙ С НАМИ!
ШКОЛА ЛЕТОВО
ЭКОТЕХНОЛОГИИ

Fig. 3. Examples of design solutions for visual propaganda tools

On April 22, 2019 (Earth Day), the school held an environmental quest, including a quiz and sports events of the appropriate environmental orientation.

On February 8, 2020, an environmental event dedicated to the recycling of used containers was organized at the school's open day.

In December 2019, a note was published in the school newspaper about the first results of the project.

In February 2020, a master class on making crafts using plastic waste was organized in school social networks.

In May 2020, a short guide was prepared and distributed in the educational environment, dedicated to sustainable lifestyles and thrifty attitude to the environment.

Conclusion. To evaluate the results of the first year of the project implementation, a repeated survey was conducted among the school community using the method described above. The main results of statistical processing of the obtained data showed the following:

1. 92.8% of respondents were satisfied or partially satisfied with the implemented scheme for placing separate waste collection bins.
2. 81.1% of the respondents were satisfied or partially satisfied with the design and informative content of visual propaganda tools.
3. 14.5% of respondents used boxes for collecting sheets used on one side daily, and another 11.6% — two or three times a week.

In total, 5.6 tons of separately collected waste were collected and put into processing during the year of work under the project. The project required almost no capital investment from the school administration and was implemented by students.

Today in Russia there are more than 40 thousand educational institutions, while separate waste collection is implemented in no more than in 5% of them. The described example shows how to solve this problem with minimal material and time costs. At the same time, a much more important aspect is the involvement of students in environmental project activities, which will not only form general academic knowledge, skills and abilities, but will also contribute to the development of moral and volitional spheres of the student's personality, provide conditions for maximum self-expression, self-affirmation and self-realization.

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Submitted 27.07.2020
Scheduled in the issue 14.08.2020

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